CHEMICAL ENGINEERING TRANSACTIONS

VOL. 38, 2014

A publication of AIDIC
The Italian Association of Chemical Engineering
www.aidic.it/cet

Guest Editors: Enrico Bardone, Marco Bravi, Taj Keshavarz

ISBN 978-88-95608-29-7; **ISSN** 2283-9216

DOI: 10.3303/CET1438027

Comparative Study on Efficiency of Biodigesters Upflow Anaerobic Sludge Blanket Treating Brewery Effluent

Ederaldo Godoy Junior[a,b,c,*], Ricardo O. Jesus[a,d], Argemiro C. Silva[d], José Rui Camargo[a,c], José R. Daniletto[e], Eugênio P. D. Coelho[b,f]

[a]University of Taubaté - Rua Daniel Danelli s/n, Zip: 12.050-720, Taubaté, SP, Brazil;
[b]Vale Soluções em Energia S.A. – Rod. Presidente Dutra, km 138, Zip: 12.247.004, São José dos Campos, SP, Brazil.
[c]Scholarship in and Productivity and Innovative Extension – CNPq
[d]Heineken Brasil S.A. Av. Pres. Humberto de Alencar Castelo Branco, 2911, Zip: 12.321-150, Jacareí, SP, Brazil
[e]PolyEasy do Brasil S.A.
[f]Federal University Itajubá
godoyjr@unitau.br; ederaldo.godoy@vse.com.br; godoyjr@pq.cnpq.br

The present work was a comparative study of four types of biodigesters systems upflow anaerobic sludge blanket (UASB) operating with brewery effluent in hot climate region. In case a UASB IC 20 meters high and 660 m^3 in volume in steel protected by epoxy resin, a conventional UASB 6 feet tall with a volume of 965 m^3 protected concrete with high density polyethylene (HDPE) film, a conventional UASB 6 feet tall with cylindrical volume of 2,000 m^3 protected steel, and end a digester system consists of two UASB arranged in series, plug flow, forming cascade of 0.5 m^3 volume at 1.2 m height each, built in HDPE rotomolded. Both systems operated hydrolyzed receiving tributary. The hydraulic retention time varied between 2.66 and 24 hours, removing the organic load of between 70% and 91% and the methane concentration between 75% and 81%. Preliminary results allowed the comparison of performance and eco-efficiency of both systems studied when objective environmental sanitation and/or bioenergization of wastewater from the brewery.

1. Introduction

The present work was a comparative study of four systems of biodigesters upflow anaerobic sludge blanket (UASB) operating with brewery effluent in a hot climate region. In this case, there was a UASB IC steel, a cylindrical steel UASB, a UASB rectangular concrete and high density polyethylene (HDPE) and also a digester system consists of two UASB plug flow in rotomolded HDPE.

According Etheridge (2003) the biogas produced in breweries in surveys conducted in Europe, has an average concentration of 60 % methane.

Yet, the biogas generated at the brewery under study, located in a region of warm weather, an average methane concentration of about 84 %.

The development of anaerobic biological applications for the purpose of removing organic matter is due to the development of the biodigester upflow anaerobic sludge blanket, developed at the Agricultural University of Wageningen in the end of the 70s (Lettinga et al. 1980).

The major factors that favor the use of the anaerobic process are low cost of implementation and operation, absence of electricity usage (does not need aeration for electrical equipment), produces low amount of excess sludge compared to aerobic systems, and cases with significant generation of biogas, can justify the energy utilization.

The biodigester UASB is basically a tank where the tributary should be distributed as evenly as possible under a blanket composed of anaerobic microorganisms, that metabolize the organic load of the effluent producing treated effluent (liquid biofertilizer), small volume of sludge (biofertilizer solid) and biogas fuel. Later the particulate biodegradable material will be stabilized by the sludge (HUANG et al., 2006)

Please cite this article as: Godoy Junior E., Jesus R.O., Silva A.C., Camargo J.R., Daniletto J.R., Coelho E.P.D., 2014, Comparative study on efficiency of biodigesters upflow anaerobic sludge blanket treating brewery effluent, Chemical Engineering Transactions, 38, 157-162 DOI: 10.3303/CET1438027

The reactor efficiency can be measured by the COD (Chemical Oxygen Demand), which equals the amount of oxygen to oxidize organic matter.

2. Materials and Methods

The research was conducted in a sewage treatment station of a brewery located in Jacarei, Brazil, latitude 23°18'19''S Longitude: 45°57'57''W, altitude: 567 meters relative to sea level. The climate, according KOPPEN is characterized as humid subtropical climate and an average temperature of 23°C. The effluent from a thermally stabilized at a temperature of 38°C brewery chemically with an average pH of 6.8 was hydrolyzed and used in the experiment.

2.1 Characterization of the sludge

The biodigester were inoculated with flocculent anaerobic sludge reactors of the brewery. The wastewater used in the experiment was of the brewery, stabilized thermally and chemically at COD of 2,090 mg/l. The flocculent sludge volume index was 20-40 ml/ g TSS. The sludge used in the reactor was pointed granules and they have up to 60 % $CaCO_3$.The presence of filamentous microorganisms interconnected with archaea Methanothrix soehngenii is predominant. According to Stokes law larger aggregates will sink faster than discrete cells of the same density. The specific mass of the sludge granules varies between 1,020 and 1,080 kg/m^3 which are similar specific masses of dispersed cells, indicating that good settling properties of the sludge of 20 to 100 m/h are due to aggregation of microorganisms. Figure 1 illustrates the sedimentation of the sludge used and a microscopic view magnified 40 times.

Figure 1: View of test sediment sludge used for inoculation of the digesters and sludge microscopic view magnified 40 times.

2.2 Characterization of affluent

The research was conducted in sewage treatment station of a brewery located in Jacarei SP, latitude 23°18'19'' S, Longitude: 45°57'57'' W, altitude: 567 meters in relation to sea level. The climate, according KOPPEN is characterized as humid subtropical climate and an average temperature of 23°C. The experiments were performed using simulated sewage effluent from the brewery. It was then possible to simulate the organic load on the input from the digesters.

2.3 Configuration UASB rectangular concrete

The rectangular UASB digester used was constructed in reinforced concrete and protected from the harsh environment of the effluent through pockets polyethylene. The concrete digester contains two distinct zones for biological conversion of effluent: The lower treatment zone contains the granular sludge in fluidized or expanded form. The modulated separator installed at the top of the reactor will capture the biogas generated in the upper zone and the entire flow of treated effluent from the system. The treated liquid leaves the system through overflow in gutters collecting effluent, conveniently distributed at the top of the reactor. This reactor has a volume of 974 m^3 and a treatment capacity of 120 m^3/h. Figure 2 illustrates the schematic drawing and a photo of the protected concrete with HDPE film studied.

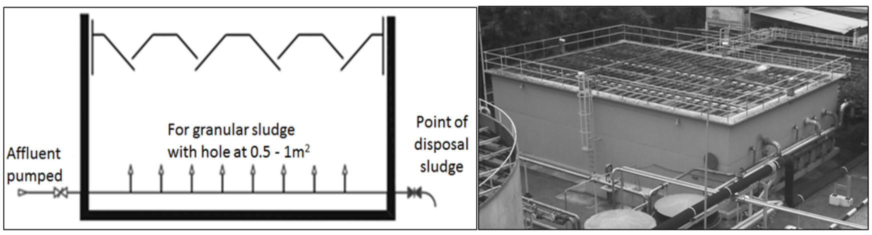

Figure 2. Design and view the UASB digester system rectangular in concrete and HDPE

2.4 Configuration UASB circular steel

The UASB circular steel digester was protected by epoxy paint and anodic protection. This reactor follows the same principle of the reactor concrete previously presented and has a volume of 2.000 m^3 and a treatment capacity of 210 m^3/h. Figure 3 illustrates a photo of the UASB circular steel studied.

Figure 3. View of the biodigester system UASB circular in steel

2.5 Configuration UASB IC steel protected with epoxy

The biodigester UASB IC in AISI 304 stainless steel has 20 meters height, volume of 664 m^3 and a treatment capacity of 250 m^3/h. The IC consists of a reactor, relatively large circular tank that contains two distinct zones for the biological conversion of the effluent: The lower treatment zone contains granular sludge in fluidized or expanded form. This zone of complete mixing is characterized by high speed upward flow of liquid. These speeds are produced by the flow of effluent fed plus the flow of internal recycle. The recycle flow is generated by the gas collected at the top of the first separator installed in the central part of the reactor and the resulting effect "gas lift", which drags the liquid mix and sludge to the top of the reactor where it is effectively mixed with the pre-acidified tributary that is entering the process. The phase separator installed at the top of the reactor captures the biogas generated in the upper zone and the entire flow of treated effluent. The treated effluent leaves the system for overflow gutters collecting effluent distributed on top of the reactor. Figure 4 illustrates the schematic view of the digester and UASB IC used in the experiment.

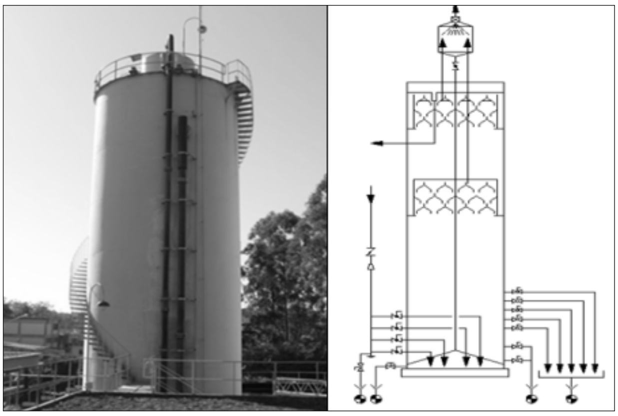

Figure 4: View of the digester system UASC IC in stainless steel AISI 304

2.6 Configuration UASB Plug Flow Polyethylene rotomolded

The bio-digester UASB plug flow was made of rotomolded polyethylene. Becuse the study was conducted in a WWTP of a brewery, the effluent already arrives with primary treatment.

As the effluent passes through the blanket of sludge, anaerobic microorganisms digest the organic matter, producing biogas on the surface of the sludge granules increasing its fluctuation.

Depending on the upward speed of the flow, the blanket of sludge expands, and some of aerated sludge granules can be dragged toward the surface.

In the separation zone of solid, liquid and gas phases, by means of a helical phase separator zone, the flow is directed to the output, the sludge granules are degassed, causing them to return to the blanket of sludge, the biogas bubbles are directed to the bell collection.

Then, the effluent passes through the other UASB arranged in series. Figures 5 and 6 illustrate drawings and view the UASB digester system Plug Flow deployed

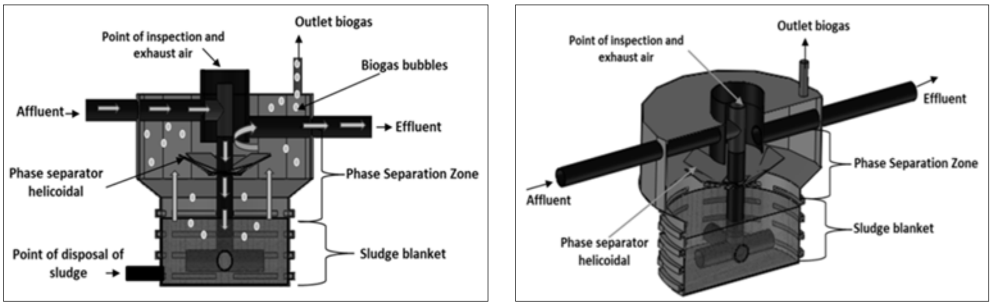

Figure 5: Schematic drawing in section details of the Optimized System Biodigestores UASB.

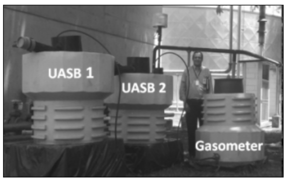

Figure 6: View of UASB System Biodigesters Plug Flow deployed in brewery in Jacareí SP Brazil.

2.7 Parameters of evaluation for the efficiency of the system

To evaluate the efficiency of the systems the following parameters were analyzed: a) COD b) BOD c) temperature d) Residence Time e) System Efficiency and f) Determination of Amount of Biogas. To measure the efficiency of the system sampling sites were at the entrance of biodigester UASB 1, the output of the biodigester UASB 1 and the output of the biodigester UASB 2.

3. Results and Discussion

3.1 UASB Plug Flow operating several hydraulic retention times

Because UASB digesters Pug Flow were connected in series, the effluent from the reactor 1 is the affluent of reactor 2. Four flows rates were simulated to confirm the best efficiency for the system as shown in Table 1, for a hydraulic retention time of 12 hours.

Table 1: Results of analysis of digesters

Flow rate (m^3/dia)	HRT (h)	COD Inlet (mg/l) UASB 1	COD Outlet (mg/l) UASB 1	COD Outlet (mg/l) UASB 2	COB_5 Inlet (mg/l)	COB5 Outlet (mg/l)	Temperature (°C)	Efficiency (%)
10	2,40	1100	638	335	550	167,5	34	69,55
7	3,43	1100	654	323	550	161,5	35	70,64
5	4,80	1100	691	285	550	142,5	33	74,09
2	12	1100	704	216	550	108	35	80

3.2 Removal of COD comparative between UASB

Table 2 shows the results of the comparison between the systems.

Table 2: Comparative characteristics of the parameters studied UASB reactors

Reator	Capacity (m^3)	Flow rate (m^3/d) (m^3/h)	HRT (h)	COD Inlet (mg/l) (mg/l)	COD Outlet (mg/l)	Flow rate biogas (Nm^3/d)	Temperature (ºC)	Efficiency %
UASB Steel N°1	2.000	3.120 210	9,52	2090	202	3.330,43	34 °C	90,33
UASB rectangular concrete N°2	974	2.880 120	8,12	2090	329	1.775	35 °C	84,26
UASC IC stainless steel N°3	664	6.000 250	2,66	2090	420	3.507	33 °C	79,90
UASB Plug Flow N°4	1	2 0,0833	12	2090	418	1,17	34 °C	80

Figure 7 shows a comparative graph of efficiency and residence time between the reactors. It can be seen that the UASB reactor in cylindrical steel has a higher efficiency than the others, but it has a high design cost and maintenance. On the other hand, the IC reactor has a retention time and lower efficiency, but it is most used in breweries because of the low design cost and maintenance as well as the ability to treat larger flows of effluent compactly.

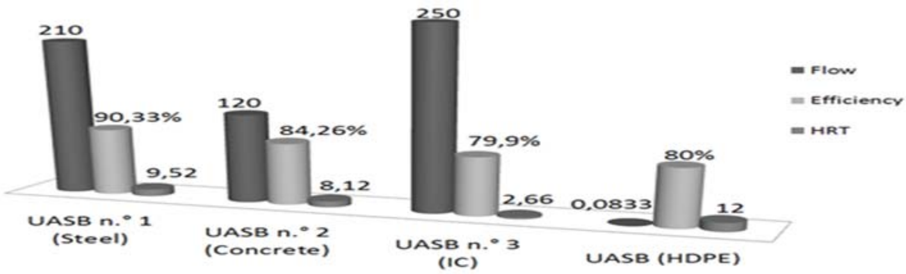

Figure 7. Comparative graph of efficiency and residence time between UASB.

3.2 Ammonia Nitrogen Removal

The analysis of ammoniacal nitrogen inlet and outlet of the reactor was performed and it was possible to identify a reduction in the output of the reactors in HDPE. Probably the reduction of ammonia is due to the reactors being connected in series. Figure 8 shows the graph of the reduction of ammoniacal nitrogen on the output of the UASB reactor Plug Flow HDPE which was 18.6 to 15.9 mg/l.

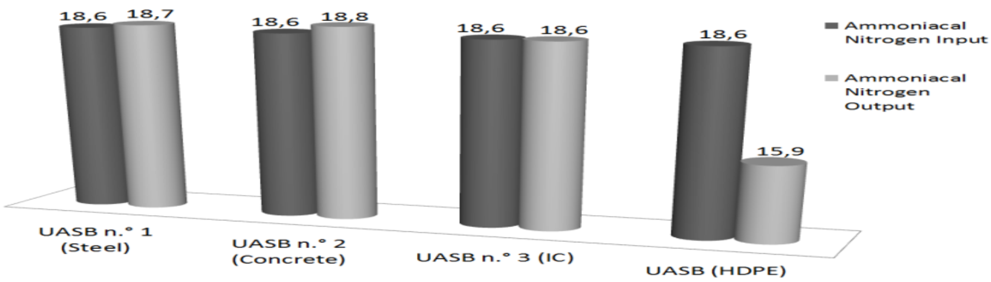

Figure 8. Graph of the reduction of ammoniacal nitrogen inlet and outlet of the reactors

In a parallel experiment using two UASB plug low, cylindrical PVC, volume 46 m^3, operates at a flow rate of 1.91 m^3/h, HRT of 24 hours, and average COD affluent of 1211.33 mg/l. The same brewer sludge was inoculated, but treating sanitary sewage, it was obtained a COD removal of 87.98%, and 16.44 of ammoniacal nitrogen. It is believed that the removal of ammoniacal nitrogen is related to its passage through more than one effluent sludge blanket.

3.3 Quality of Biogas

As Table 3 shows, the analysis of the biogas generated in the reactors was performed using the method of the gas chromatograph according to DIN 51872 (Bestimmung der Bestandteile Gaschromatographisches Verfahren).

Table 3: Comparative characteristics of biogas produced in UASB analyzed

Parameter	Unit	UASB Steel N°1	UASB rectangular concrete N°2	UASC IC stainless steel N°3	UASB Plug Flow
CO_2	%	22,03	16,04	17,77	24,80
CH_4	%	75,18	81,10	79,44	72,33
H_2S	%	0,03	0,048	0,03	0,048
N_2	%	2,50	2,615	2,40	2,615
O_2	%	0,261	0,205	0,262	0,205

4. Conclusion

After study four digesters UASB operating systems with effluent from brewery in a hot climate region, we conclude that the cylindrical UASB steel is the most efficient in the removal of organic matter, already in short time periods, In other words, periods of overload, IC is better, but has a high cost of implementation and maintenance compared to the other reactors. The cylindrical UASB steel showed the best efficiency for HRT of 9 hours. The UASB IC is the most used in breweries when there are problems to be compact area. It is noteworthy that the UASB rotational molded plug flow, has a removal efficiency of organic load very good, comparable to the IC when operated with HRT of 2.66 hours plus the cost of implementing the system is much smaller than the UASB IC, as well as maintenance because the IC any maintenance in sludge digestion column is the highest, rather risky from the point of safety, and in the case of plug flow UASB this height can be reduced to 6 meters, in addition to the gain removal of ammonia. With this, the plug flow UASB system has proved to be more feasible when compared to conventional models.

Acknowledgment

Logistical support of the UNITAU, PolyEasy of Brazil S.A., Heineken SA of Brazil and VSE (Vale Soluções em Energia S.A.). To support CNPq in the form of Productivity and Innovative Extension Scholarship.

References

ETHERIDGE, S.P., Biogas Use in Industrial Anaerobic Wastewater Treatment. In: Energy from Biogas. CETESB – Companhia de Tecnologia de Saneamento Ambiental do Estado de São Paulo. São Paulo, pp23-24 Apr 2003.

CHERNICHARO, C.A.L., Princípio do tratamento biológico de Águas Residuárias – Reatores Anaeróbios, V.5, Belo Horizonte – MG, Departamento de Engenharia Sanitária e Ambiental, Universidade Federal de Minas Gerais, 379p., 2007.

CASTRO, F.M.S., Estudo do comportamento hidrodinâmico de uma nova proposta de configuração interna de reator UASB. Dissertação de mestrado em recursos hídricos e saneamento ambiental, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, 2010, 101p.

FEACHEM, R.G., BRADLEY, D.J., GARELECK H., MARA D. D., 1983, Sanitation and Disease – Health Aspects of excreta and Wastewater Management, World Bank, John Wiley & Sons, USA.

GODOY JUNIOR, E., Desenvolvimento e avaliação de uma estação ecoeficiente de tratamento de esgoto e reuso de água, com sistema registrador queimador, para baixas vazões de biogás e cogeração de energia. Tese de doutorado em engenharia mecânica, UNESP, Guaratinguetá, SP, 2010, 149p.

GODOY JUNIOR, E., JESUS, P.H. Sistema Difusor de Efluentes para biodigestores anaeróbios de fluxo ascendente, Patente número: BR1020130172138, São Paulo, SP, 9p., 2013.

HUANG, J. et al. Consecutive reaction kinetics involving a layered Structure of the granule in UASB reactors. Water Research, 40, 2947 – 2957, 2006.

LETTINGA, G. et al. Use of Upflow Sludge Blanket (UASB) Reactor concept for Biological Wastewater Especially for Anaerobic Treatment. Biotechnology and Bioengineering, v.22, n.4, p699-734, apr. 1980.