Turkish Journal of Science & Technology
Volume 8(1), 29-36, 2013

Treatment of Slaughterhouse Wastewaters by Anaerobic Submerged Membrane Bioreactor

Mustafa ASLAN[*1], Halil ARI[1], Hakkı GÜLŞEN[1], Hakan YILDIZ[1], Yusuf SAATÇİ[2]

[1]Department of Environmental Engineering, Harran University, 63190-Şanlıurfa, Turkey
[2]Department of Environmental Engineering, Fırat University, 23119-Elazığ, Turkey
mustafaaslan63@gmail.com

(Received:19.09.2012 ; Accepted: 25.01.2013)

Abstract

Anaerobic submerged membrane (SAnMBR) system in treatment the slaughterhouse industry wastewater has a high COD with a value around 4600 mg/l and mesophilic temperature (35 ± 2°C) value, which is put into the hallow fiber membrane module with a 1.5 liters reactor system were studied. Experimental values of COD, solids, alkalinity, VFA, TP, TN, and oil-grease parameters have been measured periodically. Results of the analysis were measured the output values of COD removal efficiency of 95% with a value around 400 mg/l. Alkalinity values were decreased from 1600-1800 (mg CaCO3/l) to 1000-1200 (mg CaCO3/l). The same way as the initial values of VFA 200-300 (HoAc/l) was found, and these values are a result of treatment 120-160 (HoAc/l) were measured. While the measured initial parameters of TN and TP were 300 mg/l and 45 mg/l, respectively, these values have decreased to 240 mg/l and 15 mg/l, respectively at the system output. Though oil-grease values for the other analyses of the initial water were observed around 1000 mg/l, decreased to 45 mg/l at about 90% efficiency. The results of the analyses show that all the established anaerobic submerged membrane (SAnMBR) system was operated with high efficiency for treated slaughterhouse industry wastewater.

Keywords: Anaerobic membrane bioreactor, Treatment performance, Flux, Slaughterhouse wastewater industry

Anaerobik Batık Membran Biyoreaktör ile Mezbaha Atıksularının Arıtılması

Özet

Mezbaha sanayi atıksularından organik madde ve nutrientlerin giderilmesi amacıyla anaerobik batık membran biyoreaktör (AnSMBR) sisteminin kullanımı incelenmiştir. KOI, katı madde, alkalinite, uçucu yağ asitleri (UYA), yağ –gres, toplam azot (TN) ve fosfor (TP) gibi arıtma parametreleri periyodik olarak ölçülmüştür. Çıkış suyunda KOI 250-400 mg/L aralığında olmak üzere, %95 oranında giderim verimi belirlenmiştir. Reaktör girişinde UYA, 200-300 (HoAc/l) iken, çıkışta 120-160 (HoAc/l) olarak belirlenmiştir. TN ve TP giriş değerleri sırasıyla, 300 mg/l ve 45 mg/l iken, sistem çıkışında sırasıyla 240 mg/l ve 15 mg/l değerlerine indirgenmiştir. Besleme suyunda 1000 mg/L olan yağ-gres miktarı, %90 giderim verimi ile çıkış suyunda 45 mg/l değerine düşmüştür. Analiz sonuçları mezbaha atıksularının arıtılmasında, anaerobik batık membran biyoreaktör sisteminin yüksek oranda giderim verimleri sağladığını göstermiştir.

Anahtar Kelimeler: Anaerobik membran biyoreaktör, arıtma performansı, akı, mezbaha atıksuyu

1. Introduction

Anaerobic wastewater treatment systems have significant advantages, such as low energy consumption, less sludge production, and biogas production from waste stabilization [1]. In addition to these positive aspects of anaerobic systems also have drawbacks, in the manner that cannot provide the standards of the receiving environment and escape of microorganisms in the reactor effluents [2].

Ultrafiltration and membranes are added generally anaerobic systems to provide microfiltration [3]. In recent years, anaerobic systems combined external [4] or sunken [5] shape of membrane systems aims to resolve these problems. In particular, the submerged anaerobic membrane bioreactors (SAnMBR), has low space requirement, high-quality effluent, and can provide stable performance without being washed biomass retention in the membrane module, represents an important alternative for the implementation of anaerobic bio-technology [6-7].Taken into consideration the low growth rates of anaerobic bacteria, anaerobic membrane bioreactor technology is going to foreseen to be feasible [8]. However, the information about feasibility of the anaerobic submerged membrane (AnSMBR) system in particular the implementation of industrial wastewaters is limited [9].

Among the reported studies of the AnMBR have focused on the external membrane modules and concentrated wastewater. Typically, extremely high biomass concentration that allows a very high COD removal was obtained [10]. Anaerobic submerged membrane bioreactors are becoming attractive in recent years compared to External AnMBRs. Membrane fouling, which is the main operation problem, is related to hydrodynamic and sludge property, operating pressure, temperature, membrane material, membrane pore size, and membrane flux [9]. Optimization of operating conditions of the system should be investigated more detailed in terms of system performance and efficiency [11].

This issue has almost no full-scale applications, almost completely [9]. The study of literature is understood that the present study is very limited in the anaerobic MBR membranes and the membrane behavior is unknown. Aim of this study is treatment of slaughterhouse wastewater treatment industry whereby anaerobic submerged membrane systems, treatment performance and to investigate the efficiencies of slaughterhouse wastewater. In this context, the system will be examined to determine the performance of the operating system parameters such as COD, TOC, TS, oil-grease removal. Also measuring the the membrane flux and trans-membrane pressure, efficiency of the membrane and clogging of the membrane will be determined.

2. Material and Methods

2.1. SAnMBR System

Working used in the reactor, the feed tank, process vessel, the filtrate of the peristaltic pump discharge water, 3000 ml of the filtrate water storage tank, the membrane module (hallow fiber), temperature indicator, pressure gauge, valves, PVC and silicone connecting tubing (Figure 1) for scope of this study. Peristaltic pump speed is controlled during the forward and reverse operation (MASTERFLEX C/L). While the reactor was made of dark-colored glass and the reactor flooding container was made of transparent Plexiglas. Inlet gas collection balloon and sampling were located at the upper part of the reactor. Reactor has total liquid volume of 1.5 liters. There is a manometer in the system.
With submerged membrane bioreactor, study examined for efficiency and optimization of anaerobic membrane bioreactors for slaughterhouse wastewaters treatment. Inoculated sludge has been used in the system was obtained from anaerobic sludge digester of Pakmaya in Amasya. Slaughterhouse wastewater has been used in the system from Harranova slaughterhouse plant in Sanliurfa. MLSS and MLVSS in the mud during the exercise cycle analyses were carried out with the effluent COD. Gas formation and efficiency of COD followed and put into operation. Gas formation and efficiency of COD followed and put into operation. Samples taken from the bioreactor COD, TOC, MLSS, MLVSS, sludge volume index (SVI), the viscosity and similar analyses were carried out.

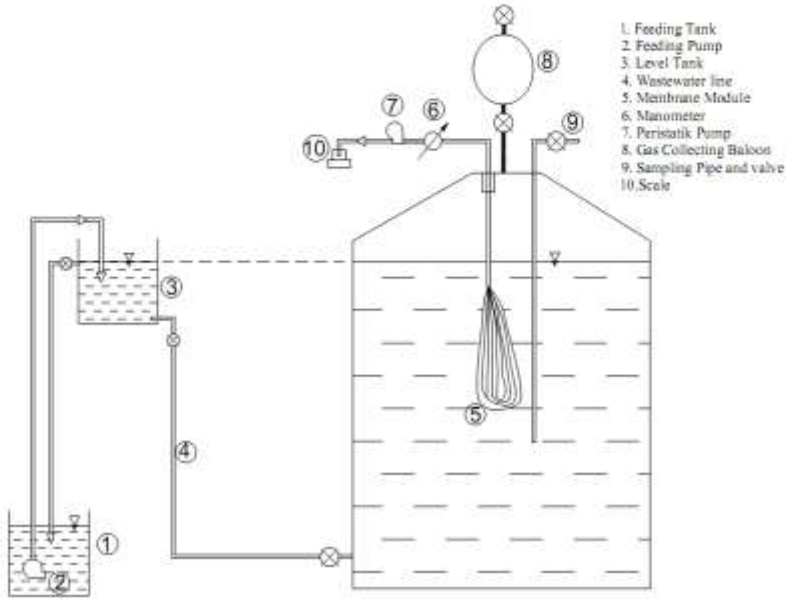

Figure 1. Schematic view of submerged anaerobic membrane bioreactor system

2.2. Wastewater and inoculation

Anaerobic sludge from digester of Pakmaya-Amasya (Turkey) sewage sludge is characterized by; sludge system was used as a inoculation. Inoculated sludge and wastewater characteristics shown in Table 1. Reactor filled with a mixture of 1/3 ratio of inoculation/synthetic wastewater, slaughterhouse wastewater were fed with later. Harranova (Şanlıurfa, Turkey) slaughterhouse wastewater plant wastewater used in the system and the wastewater has been fed with the system.

Table 1. Characteristics of Wastewater and inoculated sludge

Parameters	wastewater	inoculation
COD, mg/l	4000–5000	16000
MLSS, mg/l	1500–2200	7280
TS, mg/l	1600–3000	8100
MLVSS, mg/l	1000–1300	l6800
TN, mg/l	150	270
TP, mg/l	5	52
$SO_4^{=}$, mg/l		36
VFA, $mgCaCO_3/l$	200-500	
Cl^-, mg/l		101
pH	7–8,5	7.6
Alkalinity, $mgCaCO_3/l$	1500–1800	2450

2.3. Membrane

For treating the slaughterhouse wastewater treatment, fibers were taken when fibers of 60 cm tall hallow membrane module fibers were cut. Membrane properties used in the system are given in Table 2. An effective length of 19 cm with a U-shaped fiber membrane module was prepared.

Table 2. Membrane and Module Specifications

Membrane type	Hollow fiber – P5, Hidrofobic
Manufacturer	Zena Membranes
Pore diameter	0.1 µm
Membran materyali	Polipropilen
Typical flux	150 l/m².h, 1bar 15°C *
ID/OD	210/280 µm
pH resistance	2-11
Fiber fragmentation pressure	>5.5 bar
Fiber demolition pressure	>3.5 bar
Effective Module Areas	54,2 cm²

2.4. Analyses

2.4.1 Chemical Analyses

During the study, total nitrogen, total phosphorus, was determined by spectrophotometer using test kits of Nova 60 Spectraquant ® (Merck). Study pH values were measured by multi-parameter device. Viscosity of fluxes measured with AND Vibro-viscometer. TOC-VCPN and TNM-1 (Shimadzu, Japan) and auto sampler (ASI-V, Shimadzu, Japan) was used for some analyses. Alkalinity, COD, MLSS, MLVSS were periodically monitored according to standard methods [12].

2.4.2. Flux, trans-membrane pressure (TMP) and membrane resistance

After TMP reached 80 kPa, the membrane module in system has been changed. The system was again stopped when trans-membrane press was reached 80 kPa.

Membrane processes under fixed TMP formed of a rapid decrease in flux is expected in initial stage of filtration for membrane bioreactor filtration. To evaluate the potential for contamination of the different modes of filtration, until TMP reaches 80 kPa, flux measurements were monitored continuously, and made a detailed analysis of hydraulics was determined the total resistance based on Darcy's law in Equation 2.1:

$$J = TMP/\eta \times Rt \quad (2.1)$$

Here, J is the filtrate flux (l/m².h), Rt is the total membrane resistance (1/ m), η is the dynamic viscosity of the filtrate water (Pa.s). At the end of 75 days, while under constant pressure, the flux and dynamic viscosity is determined by measuring the total resistance.

3. Results and Discussions

3.1. TS, MLSS, MLVSS

TS values change over time as a result of the experiments is shown in Figure 2. MLSS values measured in the reactor were about 1000-1400 mg/l and decreased to around approximately 200-400 mg/l in the effluent. Likewise, while TS values change over time as measured in wastewater as seen in Figure 2 was 2000-2200 mg/l, effluent TS values decreased to around range from 700-900 mg/l.

Majority of the solid matter in permeate was occurred from dissolved substances. This situation indicates that the membrane filters can pass almost all dissolved solids.

MLSS values change over time as shown in Figure 2 was around between 1000 mg/l and 1200 mg/l however MLSS values of the effluent were decreased to about 350-450 mg/l.

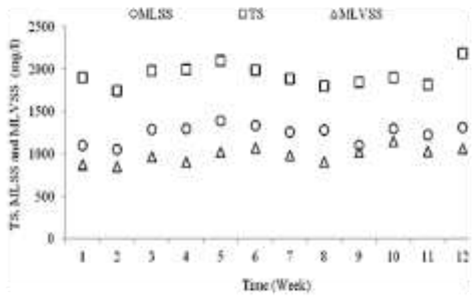

Figure 2. Change over time graph of TS, MLSS, and MLVSS

MLSS, MLVSS, and TS removal rate achieved 75-91%, 60-71%, and 60-70%, respectively. Unremoved part determined to be dissolved solids.

While raising the MLVSS of the system increases bacteriological activities at the same time cake lead to the formation on the membrane surface and causes occlusion membranes in a short time.

Fouling on the membrane surface of solid materials should be conducted in the research direction of reducing formation.

3.2. COD and COD removal rate

COD values change over time is as shown in Figure 3. The reactor system (SAnMBR) was fed with initial COD value of 4000-4600 mg/l of the slaughterhouse wastewater industry.

Slaughterhouse wastewater treatment with expanded granular bed reactor viewed study found COD removal efficiency of 79.9% with a 4.0 kg COD/m³.day organic load, and the COD removal efficiency of 64.9% with a 10.2 kg COD/m³.day organic load [13].

Reactor COD values in the reactor were ranged 500-800 mg/l. The filtrate effluent COD values were found to be range of 250-400 mg/l. COD removal efficiency was between 90-95%.

Anaerobic membrane bioreactors achieved COD removal of about 25-30% more compared to traditional anaerobic systems [13].

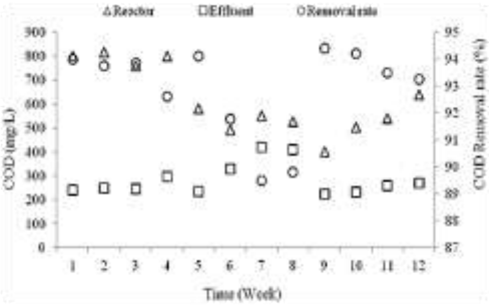

Figure 3. COD changes and COD removal efficiency

3.3 Alkalinity and VFA

Alkalinity values change over time is as shown in Figure 4. Slaughterhouse wastewater input values of alkalinity were measured between 1600-1800 mg CaCO3/l. About 40-45% removal efficiency of the alkalinity values were measured 1000 to 1200 mg CaCO3/l in the effluent.

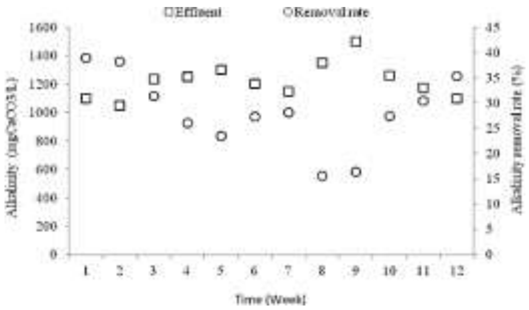

Figure 4. Alkalinity and alkalinity removal rate changes over time

VFA values have been found approximately between 200-300 mg HoAc/l in slaughterhouse wastewater. By approximately 35-45% removal efficiency, outflow values of VFA were found around 120-160 mg HoAc/l (Figure 5).VFA results suggest that the VFA was degraded by the cake layer causing membrane fouling which can act as a dynamic secondary membrane. From the VFA results can be stated that VFA causes formation of cake layer in the membrane bioreactors.

3.4. Oil and grease

Oil and grease values change over time is as shown in Figure 6.

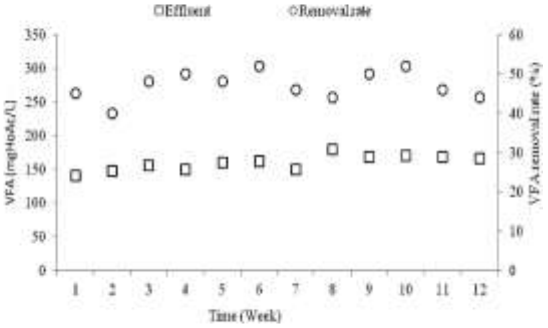

Figure 5. VFA and VFA removal rate changes over time

Wastewater input values of oil-grease were measured around above 1000 mg/l which about 95-97% removal efficiency of oil-grease values were decreased to 40 mg/l in the effluent. It is understood about these values that oil-grease removal efficiencies are higher in membrane systems.

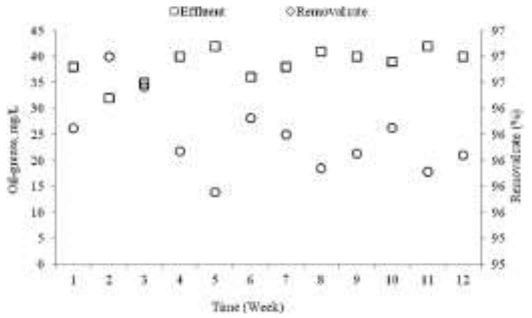

Figure 6. Oil-grease and oil-grease removal rate changes over time

Dissolved oil and grease determined passing through fully from the membrane. For this reason, oil and grease removal from slaughterhouse wastewater as a pre-treatment prior to anaerobic membrane bioreactors, will extend the life of the membranes and the obstruction of membranes are considered to decrease.

3.5. Total nitrogen (TN) and total phosphorus (TP)

TN values of slaughterhouse wastewater were found initially around 300-350 mg/l. Assembled submerged membrane system with approximately 30% efficiency, TN values were measured 240 to 280 mg/l values in the effluent

(Figure 7). Same slaughterhouse wastewater had TP values of initially 40-45 mg/l, however with a efficiency of approximately 80%, these values were found to be decreased to 7-15 mg/l (Figure 8). A study on treatment of slaughterhouse wastewater [14], influent of wastewater with 120-221 mg/l $NH4^{+}$-N in a reactor reported as 300-506 mg/l $NH4^{+}$-N in the effluent. In other words, nitrogen increase found. In our study, data were obtained the opposite direction. Aside from the increase in nitrogen removal is achieved in our study. Traditional anaerobic systems, nitrogen and phosphorus removal are known to be very low. In our study, both phosphorus and nitrogen removal rate were reached. Nitrogen and phosphorus removal are known to be very low in classical anaerobic systems.

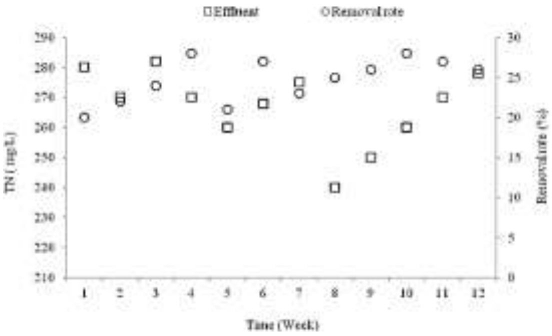

Figure 7. TN and TN removal rate changes

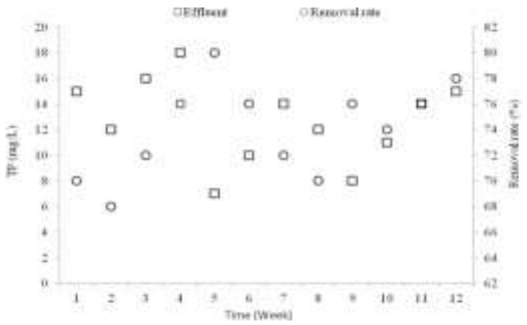

Figure 8. TP and TP removal rate changes

3.6. Flux and TMP

The results of the flux and transmembrane pressure measurement are shown in Figure 9. According to these results, sudden changes were observed in 13th and 23rd days. After looking more carefully to experiment journal, this sudden drop was determined due to the change of the membrane in the system.

Decrease in flux on short time on slaughterhouse wastewater anaerobic treatment of submerged membrane bio-reactors can be connected to cake formation on the membrane surface. This situation is caused by membrane fouling. These systems are seen to be optimal for fouling issues are resolved.

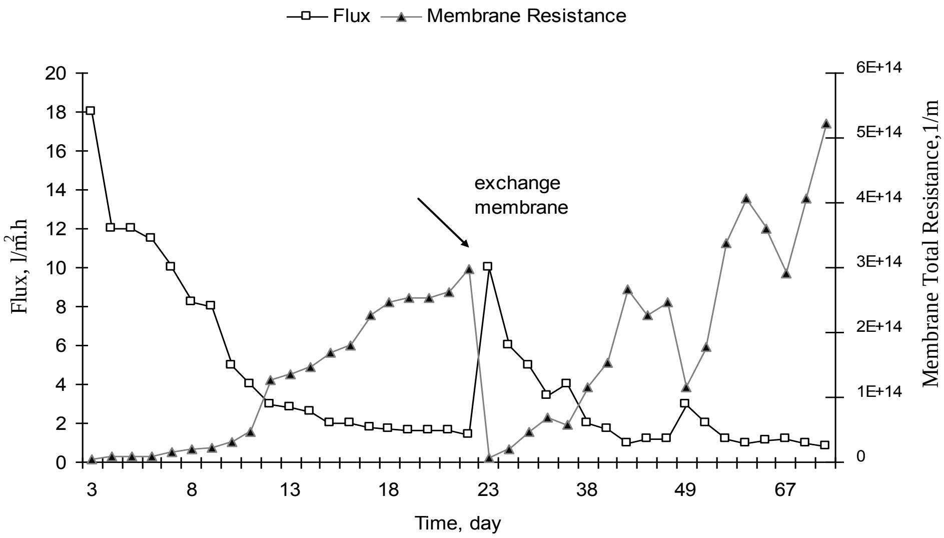

Figure 9. Flux and TMP results

4. Conclusions

In this study, slaughterhouse wastewater treated by anaerobic conditions by the submerged membrane bioreactor system has been achieved high efficiencies. The results have been found in the system as following.

MLSS and MLVSS are reduced to range of 95-98% in the system. Decreased in the majority of the solid material were found as dissolved solids. Results of the analysis were measured the output values of COD removal efficiency around 95%. VFA removal rates were obtained around 35-45%. Removal efficiency of total nitrogen and total phosphorus has been obtained around 30% and 70%, respectively. Oil-grease removal efficiency was as high as 97% in membrane systems.

In terms of flux and membrane contamination resistance was determined that blockage quickly. Membrane fouling problem need to be explored in detail for future study. Once this kind of disadvantages will be solved, occurrence of high removal efficiencies in submerged membrane systems found, whereby slaughterhouse wastewater treatment will be optimal.

Acknowledgement:

This study was supported by the Harran University Scientific Research Center with Project no: 1038.

6. References

1. Cicek, N. (2003). A review of membrane bioreactors and their potential application in the treatment of agricultural wastewater. Can. Biosyst. Eng. 45(6),37–49.

2. Lew, B., Belavski, M., Admon, S., Tarre, S. and Green, M. (2003). Temperature effect on UASB reactor operation for domestic wastewater treatment in temperate climate regions, Water Sci. Technol., 48 (3) 25-30.

3. Stephenson, T., Turra, E. and Jefferson, B. (2003). Biomass characterization in membrane bioreactors. in: Proceedings of the IMSTEC, Sydney, Australia.

4. Ho, J., Khanal, S.K., Sung, S. (2007). Anaerobic membrane bioreactor for treatment of synthetic municipal wastewater at ambient temperature. Water Sci. Technol., 55 79–86.

5. Hu, A.Y.,and Stuckey, D.C. (2006). Treatment of dilute wastewaters using a novel submerged anaerobic membrane bioreactor. Journal of Environmental Engineering, 132 (2), 190–198.

6. Saddoud, A., Hassairi I. and Sayadi, S. (2007). Anaerobic membrane reactor with phase separation for the treatment of cheese whey, Bioresource Technol., 98, 2102–2108.

7. Ho, J., and Sung, S., (2010). Methanogenic activities in anaerobic membrane bioreactors (AnMBR) treating synthetic municipal wastewater, Bioresource Technology, 101 (7), 2191–2196.

8. Jeison, D. and van Lier, J.B., (2006). Cake layer formation in anaerobic submerged membrane bioreactors (AnSMBR) for wastewater treatment, Journal of Membrane Science, 284, 227–236.

9. Liao, B.Q., Kraemer, J.T., Bagley, D.M., (2006). Anaerobic membrane bioreactors: Applications and research directions. Critical Reviews in Environmental Science and Technology, 36 (6), 489-530.

10. Fuchs, W., Binder, H., Mavrias, G., Braun, R., (2003). Anaerobic treatment of wastewater with high organic content using a stirred tank reactor coupled with a membrane filtration unit, Water Research, 37 (4), 902-908.

11. Meng, F., Chae, S.-R., Drews, A., Kraume, M., Shin, H.-S., Yang, F., (2009). Recent advances in membrane bioreactors (MBRs): membrane fouling and membrane material. Water Res., 43 (6), 1489–1512.

12. APHA, AWWA, (1992). Standard Methods for the Examination of Water and Wastewater, 16 th Ed.

13. Nunez, B.A., Martinez, B. (1999), Anaerobic Treatment of Slaughterhouse Wastewater in an Expanded Granular Sludge Bed (EGSB) Reactor, Water Science and Technology, 40 (8) 99-106.

14. Masse, L., and Masse, D.I., (2005). Effect of soluble organic, particulate organic, and hydraulic shock loads on anaerobic sequencing batch reactors treating slaughterhouse wastewater at 20 C, Process Biochemistry, 40, (3–4), 1225–1232.

PRINTED ISSN:1308-9080, ONLINE ISSN:1308-9099
Turkish Journal of Science and Technology
Uluslararası Hakemli Dergi/Journal with International Referee
Altı ayda bir yayınlanır (Mart, Eylül)
Published six-montly (March, September)

Yıl/Year : 2013
Cilt/Volume : 8
Sayı/Number : 1

EBSCO PUBLISHING veri tabanında taranmaktadır
Indexed in EBSCO PUBLISHING index

Yazışma Adresi/Address of Corespondence
Fırat Üniversitesi Fen Bilimleri Enstitüsü, 23119-Elazığ, Türkiye
http://web.firat.edu.tr/fenbilimleri/Dergiler/TJST/index.html

T. Nuri DURLU	Ankara University Department of Physics
Mehmet KİTİŞ	S.D.U., Department of Environmental Engineering
İbrahim TURKMEN	Balıkesir University, Dept. of Geology Engineering
Ali DEMIR	ITU, Department of Textile Engineering
Wang XIBAO	Tianjin Uni.The School of Materials Sci. and Eng.
Hasan EFEOGLU	Ataturk University, Dept. of Electrical-Electronics Engineering
Saleem HASHMI	International College of Technology, Dublin, Ireland
Özcan ÖZTÜRK	Bilkent University, Department of Computer Engineering
Sakir ERDOGDU	KTU, Department of Civil Engineering
Yanhui GUO	St. Thomas University, School of Science and Technology
Brain WOERNER	West Viriginia Uni., Dept. of Comp. Sci.& Elect. Eng.
Eoin CASEY	University College Dublin, Chemical and Bioprocess Eng.
Farid El-Tantawy	Suez Canal University, Department of Physics
A. Kadri CETIN	Fırat University, Department of Biology
Ahmet BAYLAR	Fırat University, Department of Civil Engineering
Deniz UNER	METU, Department of Chemical Engineering
Sedigheh GHOFRANI	Islamic Azad University, Electrical Engineering Department

8(1) Sayısının Hakemleri/Referees for 8(1) Issue

Elgiz BAYRAM	Ankara U.
Ömer AKIN	T.O.B.B. U.
Mustafa İNÇ	Fırat U.
Alaattin ESEN	İnönü U.
Yavuz EROL	Fırat U.
Zeydin PALA	Muş Alparslan U.
Yakup CUCİ	Kahramanmaraş U.
Yağmur UYSAL	Kahramanmaraş U.
Şemsettin OSMANOĞLU	Dicle U.
Hafiz ALİSAOY	İnönü U.
Mehmet GÜLCAN	Fırat U.
Ayşe TURAN	Fırat U.
Fethi KAMIŞLI	Fırat U.
Halil HOŞGÖREN	Dicle U.
Gül CEVAHİR	İstanbul U.
Metin DIĞRAK	Kahramanmaraş U.