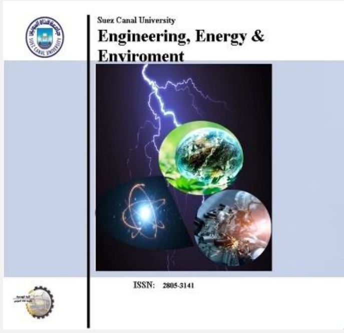
Suez Canal Engineering, Energy and Environmental Science Journal

https://sceee.journals.ekb.eg/

Vol 1, No. 1, 13-17



Improving the stability and biogas production of UASB reactor; parametric and microbial study

[1]Aya Mohamed, [2]Abeer El-Shahawy, [3]Sahar EL-Shatoury , [4]Ahmed Aboulfotoh , [5] Dalia Ahmed

[1] Teaching Assistant, Environmental Engineering Department, Faculty of Engineering, Suez Canal University, Ismailia, Egypt
[2]Associate Professor, Environmental Engineering Department, Faculty of Engineering, Suez Canal University, Ismailia, Egypt
[3]Professor, Microbiology Department, Faculty of Science, Suez Canal University, Ismailia, Egypt
[4]Associate Professor, Environmental Engineering Department, Faculty of Engineering, Zagazig University, Zagazig, Egypt
[5]Assistant Professor , Environmental Engineering Department, Faculty of Engineering, Zagazig University, Zagazig, Egypt

Abstract - In areas without sewer collection infrastructure, decentralized treatment is regarded as being necessary to provide sewage management and sanitation. Organic matter can be degraded anaerobically with Up-flow Anaerobic Sludge Blanket (UASB) digesters resulting in biogas production that is used in a wide range of uses (i.e., for heating, electricity, and fuel). Under decentralized operations, traditional aerated wastewater treatment can be expensive and readily overloaded by high-strength effluent or changes in the environment's temperature. High-strength wastewater can be treated with UASB digesters, which can also produce biofuel and reduce the high costs of aeration. Operations can be stabilized and granule formation improved by adding supporting components such as microbial communities and biochar made from Phragmites Australis to the UASB. The first stage of this study statistically investigates the optimization of anaerobic treatment conditions of cattle wastewater in a batch study. In the second stage, continuous treatment processes will be planned using data obtained as a result of the batch study. The COD concentrations used in the present study ranged between 1850 mg/L to 2050 mg/L while the BOD concentrations range between 450 mg/L to 1250 mg/L. The effects of operating parameters on the chemical oxygen demand (COD) removal efficiency and the methane production rate were evaluated. COD removal efficiencies of 72.43% –92.70% were obtained for the cattle wastewater using a 3–14 d hydraulic retention time. The maximum COD removal was found in batch experiment 7, where the type of bacteria was actinobacteria, biochar dose was 20 g/L, pH was 7.5 and no inoculum dose was added this resulted in 92.70% COD removal efficiency. Hence, the batch study recommended using actinobacteria as a type of bacteria and Phragmites Australis biochar for continuous UASB reactors.

Keywords:
Up-flow anaerobic sludge blanket, Anaerobic digestion, Decentralized, Biogas, Biochar, Phragmites Australis, Microbial communities, chemical oxygen demand, Biological oxygen demand.

I. INTRODUCTION

A significant obstacle to sustainable development is water shortage. This challenge is compounded by rapid population growth, urbanization, environmental pollution, and climate change [1]. As a result, technologies that reduce water shortages and increase water supply must be developed and improved, one of which is municipal wastewater treatment.

It indicates that biological wastewater treatment is a viable technique. It is possible to use both aerobic and anaerobic procedures. In the former, microbes use dissolved oxygen to transform organic materials into biomass and CO_2. In the latter, complex organic wastes are transformed into methane, CO_2, and water in the absence of oxygen [2].

The best choice for treating wastewater is anaerobic treatment. It offers various advantages, such as low energy needs, low sludge generation, and low sludge treatment costs [3, 4]. Other advantages can include the generation of renewable energy from methane, emission mitigation, and possibly hydrogen energy [4].

DOI: 10.21608/SCEEE.2023.279485

Up-flow anaerobic sludge blanket (UASB) reactors are one of the various designs of anaerobic treatment systems. They are potential anaerobic systems, particularly in underdeveloped nations with warm-water climates. Warm climates frequently use anaerobic technology to treat low-strength streams at ambient temperature[5].

UASB reactors are systems with a very robust rate of treatment because they are simple to use, have minimal construction and running costs, as well as being efficient, and flexible, and have a smaller footprint and relatively high-quality effluent [6].

However, when used as a single treatment process, UASB systems still have significant limitations. One of these constraints is a lack of ability to remove organic matter and nitrogen, resulting in the effluent stream failing to meet effluent discharge standards [7]. The mentioned constraints of UASB reactors can be mitigated by enhancing effluent quality through a variety of approaches, which can be divided into two major trends.

The first tendency is to change the configuration of the UASB reactor. Musa et al. [6], for example, enhanced the efficiency of a UASB by using a solid separator in the upper part just above the sludge blanket, preventing sludge washout from the reactor. The second trend in meeting UASB effluent regulations is to choose a suitable post-treatment technique[8] .

Guiot and van den Berg [9] proposed an anaerobic hybrid UASB reactor with the following configuration: the UASB reactor was in the lower zone while filling media was added in the upper zone to provide additional biomass growth surface area. When compared to traditional UASB, hybrid UASB has several advantages, including faster biomass granulation, a shorter startup period, and higher loading rates [1, 10].

The original UASB configuration was modified in a number of scientific studies to satisfy a particular purpose, such as producing hydrogen or VFA (rather than methane), or increasing reactor performances through the introduction of supporting materials[11]. Different materials were proposed for packing UASB reactor, including granular activated carbon (GAC), and carbon cloth (CC). Also, magnetite and hematite are the most common metal-based SMs applied in AD., minerals, recycled plastic material, synthetic grass and biochar [12].

The principal objective of this study is to improve water quality through an anaerobic system for wastewater recovery and bioenergy generation applicable system on Suez Canal University Experimental Farm. The primary objective is to test a system that combines wastewater pretreatment, and up-flow anaerobic sludge blanket (UASB) digestion, installed at Suez Canal University Experimental Farm.

II. MATERIALS AND METHODS.

2.1. Wastewater Characteristics

The experimental reactors were installed and operated in the field at Suez Canal University veterinary experimental Farm in, Ismailia, Egypt. The wastewater utilized was real cattle wastewater with variable characteristics. The reactors were fed with gritted wastewater using a submerged pump. To mitigate the flow-rate variation, a constant head tank was installed ahead of the reactors. A summary of the characteristics of the influent wastewater is given in Table 1.

Table 1. Influent wastewater characteristics.

Parameters	Mean Value
pH	7.9
BOD, mg/L	980
COD, mg/L	2050
TSS, mg/L	1388
TDS, mg/L	1060
NH_3 , mg/L	16.7
Alkalinity, mg/L	317

2.2. Experimental design

This statistical study was preferred based on a factorial experimental design that would allow us to infer the effect of the variables with relatively few numbers of experiments. The independent variables of the experimental design are shown in Table 2. Biochar dose, Inoculum dose, Type of bacteria, and pH concentrations received two values: a high value (shown by the plus sign), and a low value (shown by the minus sign).

Table 2. The independent variables and their levels for the experimental design

Variables	Levels	
	-1	1
Biochar dose g/L	2	20
Inoculum dose %	0	5
pH	5.5	7.5
Type of bacteria	Pseudomon.	Actino.

2.3. Preparation of biochar (*P. australis*)

According to [13] *P. australis* was collected from Suez Canal University veterinary experimental Farm at, Ismailia, Egypt. The precursor was first washed with distilled water to remove surface-adhered dirt, filth, and water-soluble materials and then dried. The dried *P. australis* was crushed in a laboratory mill and sieved to obtain particles ranging from 1–2 mm. After that, the mass was then transferred to a pyrolysis reactor and heated slowly to reach the desired temperature of 550 °C, shown in **Fig. 1**, It was kept under the temperature for 2 h and then cooled down to room temperature.

The pyrolyzed product was washed repeatedly with distilled water until neutral pH was obtained and then dried overnight in a dried oven at 110 °C. The dried sample of *P. australis* biochar (PABC) was ground and sieved to 200 mesh particle size by standard sieves (Model Φ200) before storage and further testing. The PABC was then stored in a desiccator for later experimental use[14, 15].

Fig. 1 Pyrolysis reactor

2.4. Sampling and Analytical Methods

Samples of the influent and the effluents of the anaerobic reactors were collected and analyzed. All the samples, chemical solutions, and experiments were prepared using ultrapure water. Grab samples of the influent thus collected were analyzed for physio-chemical-biological parameters viz. pH, COD, BOD, TDS, TSS, NH_3, and Alkalinity as per the methods described in "standard methods for the examination of water and wastewater" American Public Health Association (APHA, 2017), Listed in Table 3. And the effluents of the UASB reactor were sampled for pH and COD analysis[16, 17].

The volume of methane produced will be measured daily by the liquid displacement method after removing CO2 by adsorption into the KOH solution[18]. Samples were collected in duplicate and the sampling duration was 0.5hr and 1L.

Sample of both influent and UASB effluent were coll-ected in sterilized bottle and were protected from direct sunlight during transportation. All samples were stored under refrigeration at 4 C until analyzed and after proper preservation immediately transported to Suez Canal University's Centre for Environmental Studies and Consultants in Ismailia, Egypt. to evaluate selected parameters. The samples were analyzed within 4 hrs. of collection[19] .

Table 3. Analytical Methods Used for evaluation of various parameters

Parameters	Analytical Method as per Standard
pH	pH meter (LI 614 ELICO pH analyzer)
COD (Soluble and Total)	Open Reflux Method
BOD (Soluble and Total)	Five Days incubation at 27°C
Total Solid	Total Solids dried at 103 -105°C
Suspended Solid	Suspended Solids dried at 103-105°C
Volatile Suspended Solid	Volatile Suspended Solid ignited at 550°C

III. RESULTS AND DISCUSSIONS

3.1. Batch experiment

A full 2^4 experimental setup, which required 16 different experiments, shown in Fig. 2, was used in this experimental design. In this experimental factorial design (2^4), the effects of variable parameters were investigated with anaerobic batch experiments. In addition, Table 4 shows the results obtained in terms of % COD removal. The maximum COD removal was found in experiment 7, where the type of bacteria was actinobacteria, biochar dose was 20 g/L, pH was 7.5 and no inoculum dose was added this resulted in 92.70% COD removal efficiency. Calculated as shown in the equation. 1,

$$E = \frac{\text{CODin} - \text{CODef}}{\text{CODin}}\ x\ 100\ \%\ \ldots \quad \text{eq (1)}$$

Where E is the removal efficiency of COD (%), COD_{in} and COD_{ef} is the influent and the effluent chemical oxygen demand (mg/L), respectively.

The estimation of the average effect and the main effects (the effect of each variable) on the response and the two higher-order interactions were calculated using the statistical software Minitab 19.

Fig. 2 Batch experiments

Table 4. Full factorial (2^4) experimental design and results of COD removal.

Experiments	Biochar dose	Inoculum dose	pH	Type of bacteria	COD removal (%)
1	2	0	7.5	Pseudo.	89.46%
2	2	0	5.5	Actino.	88.65%
3	2	5	5.5	Actino.	81.35%
4	2	0	7.5	Actino.	90.81%
5	2	5	5.5	Pseudo.	82.97%
6	2	0	5.5	Pseudo.	77.84%
7	20	0	7.5	Actino.	92.70%
8	2	5	7.5	Actino.	87.03%
9	20	5	5.5	Actino.	45.68%
10	20	5	7.5	Actino.	42.97%
11	20	0	5.5	Actino.	45.95%
12	20	0	7.5	Pseudo.	55.68%
13	20	5	5.5	Pseudo.	42.97%
14	2	5	7.5	Pseudo.	40.27%
15	20	0	5.5	Pseudo.	46.22%
16	20	5	7.5	Pseudo.	72.43%

DOI: 10.21608/SCEEE.2023.279485

3.1.1 Effect of Biochar dose , Inoculum dose, pH , and Type of bacteria on COD removal

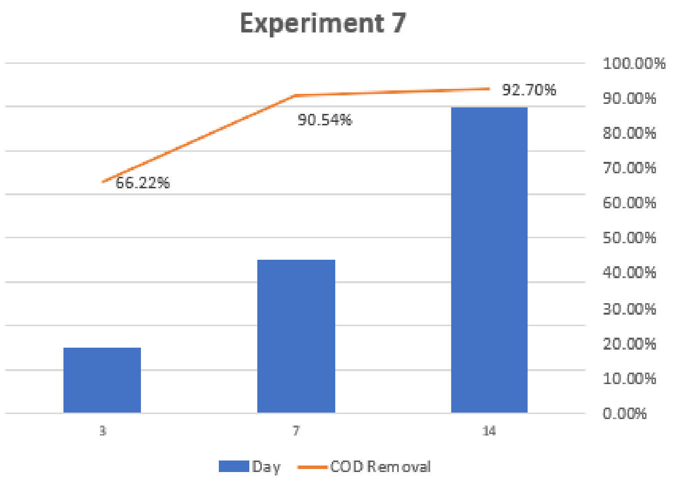


Fig. 3 COD removal efficiency of experiment 7 of batch experiments.

3.2. Up-Flow Anaerobic Sludge Blanket Reactor

After the batch experiment finished, the continuous up-flow anaerobic sludge blanket (UASB) reactor will be started. five pilot-scale UASB reactors, shown in **Fig**. 4, which were made of PVC cylinders (effective height 150 cm and 10 cm internal diameter) will be used in this study, two 2 for investigating the effect of using supporting media and the third one will be used to evaluate the effect of pretreatment and the use of other materials of the performance of the UASB reactors.

Sewage will be transferred to the reactors from a storage tank by using pumping. The flow rate will be changed from 35 (l/d) to 70 (l/d) with a hydraulic retention time (HRT) of 4 to 8 hrs.

In accordance with the batch reactor results. The reactor will be fed with actinobacteria as a type of bacteria and Phragmites Australis biochar for anaerobic wastewater treatment.

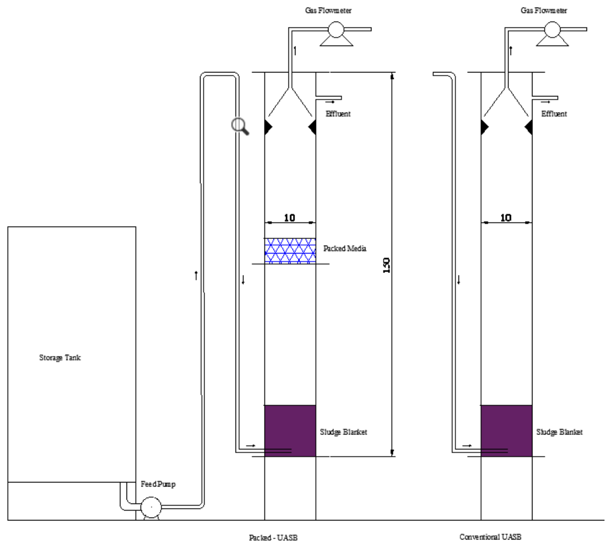


Fig. 4 Up Flow Anaerobic Sludge Blanket Reactor (UASB)

3.2.1 Mean values of COD for influent and Effluent of UASB reactor in case of conventionally working without any additions

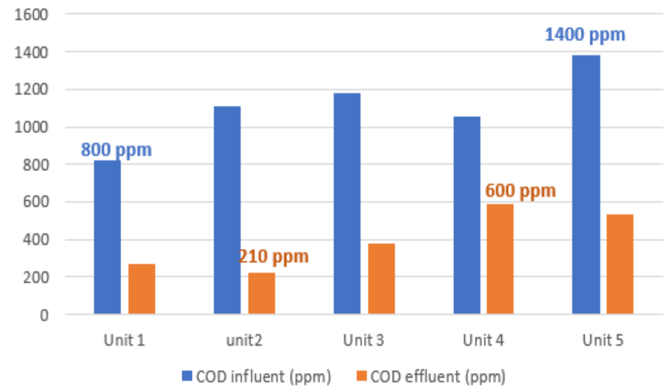


Fig. 5 COD removal efficiency of UASB reactors.

3.2.2 Mean values of COLOR for influent and Effluent of UASB reactor in case of conventionally working without any additions

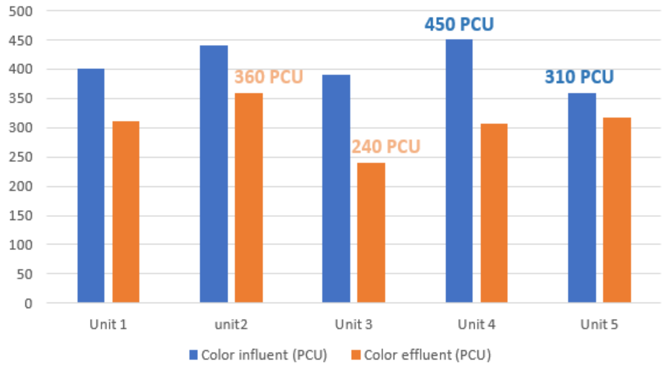


Fig. 6 COLOR removal efficiency of UASB reactors.

3.2.3 Mean values of TURBIDITY for influent and Effluent of UASB reactor in case of conventionally working without any additions

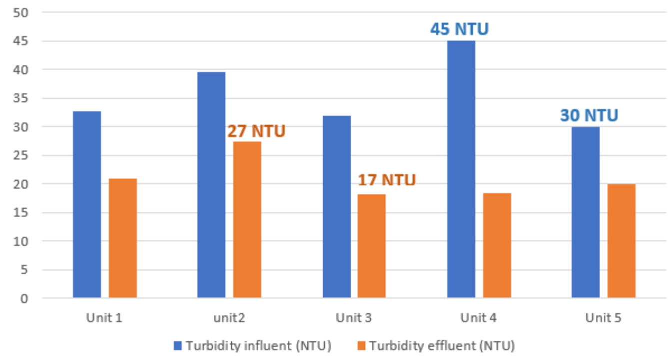


Fig. 7 TURBIDITY removal efficiency of UASB reactors.

DOI: 10.21608/SCEEE.2023.279485

IV. CONCLUSION

According to the batch results, the maximum COD removal efficiency was observed in batch experiment 7, where the type of bacteria was *Streptomyces hydrogenans* S11, the biochar dose was 20 g/L, pH was 7.5 and no inoculum dose was added this resulted in 92.70% COD removal efficiency. Hence, the batch study recommended using actinobacteria as a type of bacteria and Phragmites Australis biochar for continuous UASB reactors. Results will be obtained in the further work of continuous UASB reactors later on.

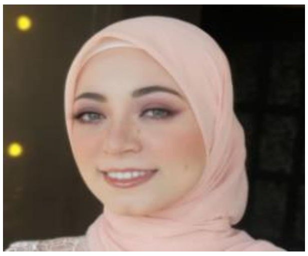
ACKNOWLEDGEMENT

The authors thank Suez Canal University's Centre for Environmental Studies and Consultants in Ismailia, Egypt.

REFERENCES

1. Liu W, Song X, Huda N, Xie M, Li G, Luo W. Comparison between aerobic and anaerobic membrane bioreactors for trace organic contaminant removal in wastewater treatment. Environmental Technology & Innovation. 2020 Feb 1;17:100564.
2. Chan YJ, Chong MF, Law CL, Hassell DG. A review on anaerobic–aerobic treatment of industrial and municipal wastewater. Chemical engineering journal. 2009 Dec 1;155(1-2):1-8.
3. Chong, S., Sen, T. K., Kayaalp, A., & Ang, H. M. (2012). The performance enhancements of upflow anaerobic sludge blanket (UASB) reactors for domestic sludge treatment–a state-of-the-art review. Waterresearch, 46(11),3434-3470
4 Show, K. Y., Yan, Y. G., Zhao, J., Shen, J., Han, Z. X., Yao, H. Y., & Lee, D. J. (2020). Laboratory trial and full-scale implementation of integrated anaerobic-aerobic treatment for high strength acrylic acid wastewater. Science of the Total Environment, 738, 140323.
5. Chong, S., Sen, T. K., Kayaalp, A., & Ang, H. M. (2012). The performance enhancements of upflow anaerobic sludge blanket (UASB) reactors for domestic sludge treatment–a state-of-the-art review. Water research, 46(11), 3434-3470.
6. Musa, M. A., Idrus, S., Che Man, H., & Nik Daud, N. N. (2019). Performance comparison of conventional and modified upflow anaerobic sludge blanket (UASB) reactors treating high-strength cattle slaughterhouse wastewater. Water, 11(4), 806.
7. Allegue, T., Carballo-Costa, M. N., Fernandez-Gonzalez, N., & Garrido, J. M. (2020). Simultaneous nitrogen and dissolved methane removal from an upflow anaerobic sludge blanket reactor effluent using an integrated fixed-film activated sludge system. Journal of environmental management, 263, 110395.
8. de Mendonça, H. V., Ometto, J. P. H. B., Otenio, M. H., Dos Reis, A. J. D., & Marques, I. P. R. (2017). Bioenergy recovery from cattle wastewater in an UASB-AF hybrid reactor. Water Science and Technology, 76(9), 2268-2279.
9. Guiot, S. R., & Van den Berg, L. (1985). Performance of an upflow anaerobic reactor combining a sludge blanket and a filter treating sugar waste. Biotechnology and Bioengineering, 27(6), 800-806.
10. Khan, A. A., Gaur, R. Z., Tyagi, V. K., Khursheed, A., Lew, B., Mehrotra, I., & Kazmi, A. A. (2011). Sustainable options of post treatment of UASB effluent treating sewage: a review. Resources, Conservation and Recycling, 55(12), 1232-1251.
11. Yu, N., Guo, B., Zhang, Y., Zhang, L., Zhou, Y., & Liu, Y. (2021). Self-fluidized GAC-amended UASB reactor for enhanced methane production. Chemical Engineering Journal, 420, 127652.
12. Zhang, Y., Guo, B., Dang, H., Zhang, L., Sun, H., Yu, N., ... & Liu, Y. (2022). Roles of granular activated carbon (GAC) and operational factors on active microbiome development in anaerobic reactors. Bioresource technology, 343, 126104.
13. Chen, S., Zhang, J., Zhang, C., Yue, Q., Li, Y., & Li, C. (2010). Equilibrium and kinetic studies of methyl orange and methyl violet adsorption on activated carbon derived from Phragmites australis. Desalination, 252(1-3), 149-156.
14. Wang, Q., Liang, J., Zhan, Y., Yao, X., Liu, Z., Li, Q. X., ... & Yoza, B. A. (2018). Treatment of petroleum wastewater using an up-flow anaerobic sludge blanket (UASB) reactor and turf soil as a support material. Journal of Chemical Technology & Biotechnology, 93(11), 3317-3325.
15. Li, R., Zhou, M., He, S., Pan, T., Liu, J., & Zhu, J. (2021). Deciphering the effect of sodium dodecylbenzene sulfonate on up-flow anaerobic sludge blanket treatment of synthetic sulfate-containing wastewater. Frontiers of Environmental Science & Engineering, 15, 1-12.
16. Buchauer, K. (1998). A comparison of two simple titration procedures to determine volatile fatty acids in influents to waste-water and sludge treatment processes. WATER SA-PRETORIA-, 24, 49-56.
17. Collivignarelli, M. C., Abbà, A., Caccamo, F. M., Calatroni, S., Torretta, V., Katsoyiannis, I. A., ... & Rada, E. C. (2021). Applications of up-flow anaerobic sludge blanket (UASB) and characteristics of its microbial community: a review of bibliometric trend and recent findings. International Journal of Environmental Research and Public Health, 18(19), 10326.
18. Akcal Comoglu, B., Filik Iscen, C., & Ilhan, S. (2016). The anaerobic treatment of pharmaceutical industry wastewater in an anaerobic batch and upflow packed-bed reactor. Desalination and Water Treatment, 57(14), 6278-6289.
19. Hussain, A., & Dubey, S. K. (2017). Specific methanogenic activity test for anaerobic degradation of influents. Applied water science, 7, 535-542.

AUTHORS BIOGRAPHY

	Teaching Assistant
	Associate Professor
	Professor

DOI: 10.21608/SCEEE.2023.279485