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Effect of Supporting Conductive Materials on Up-Flow Anaerobic Sludge Blanket Performance

[1]Nehal Nessem , [2]Abeer El-Shahawy, [3]Sahar EL-Shatoury , [4]Dalia Ahmed
[1] Environmental Engineering Department, Faculty of Engineering, Suez Canal University, Ismailia, Egypt, email:nehal.nessem@eng.suez.edu.eg
[2] Environmental Engineering Department, Faculty of Engineering, Suez Canal University, Ismailia, Egypt, emai:abeer_shahawi@eng.suez.edu.eg
[3]Microbiology Department, Faculty of Science, Suez Canal University, Ismailia, Egypt, email: sahar_hassan@science.suez.edu.eg
[4] Environmental Engineering Department, Faculty of Engineering, Zagazig University, Zagazig, Egypt, email:dahmed@zu.edu.eg.
**Corresponding author, Email address: nehal.nessem@eng.suez.edu.eg*
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Abstract

The addition of supporting components, such as biochar derived from rice straw, to the Up-flow Anaerobic Sludge Blanket (UASB), can enhance operational stability and promote the production of granules. The initial phase of this study employs statistical analysis to examine the optimization of anaerobic treatment settings for buffalo effluent in a batch study. During the second phase, the design of continuous treatment processes will be based on data acquired from the batch study. An assessment was conducted to determine the impact of operational parameters on the efficiency of removing chemical oxygen demand (COD) and the rate of methane production. The maximum removal of COD (85%) of Rice Straw Biochar (RSB) was at pH value, biochar dose, and inoculation concentration were equal to 8, 2 g/L, and 0%, respectively, in batch experiment 3. Commercial Activated Carbon (AC) has achieved maximum removal of COD (81%), and pH, biochar dose, and inoculation concentration were equal to 5, 2 g/L, and 0%, respectively, in batch experiment 1. The maximum removal of COD (83%) of Phragmites australis Biochar (PaB) was at pH, biochar dose, supporting Material, and inoculation concentration were equal to 5, 2 g/L, and 0%, respectively, batch experiment 12.

Keywords: *Up-flow anaerobic sludge blanket, Methane production, Biochar, Rice straw, Phragmites Australis, Commercial Activated Carbon, Chemical oxygen demand.*

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1. INTRODUCTION

Wastewater from different sectors such as food and beverage, textile, agriculture, and households (containing urine, feces, and kitchen waste) is a valuable energy resource due to its content of organics (measured as chemical oxygen demand, or COD, and biological oxygen demand, or BOD) and nutrients (N, P, and K) that can be extracted or converted

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into valuable products like methane and chemicals. The treatment procedure must be efficient and cost-effective in its operation and maintenance. Land needs significantly influence the selection of treatment techniques. Anaerobic treatment technologies hold significant promise in the majority of developing nations [1].

Anaerobic and aerobic processes may be employed. Aerobic processes utilize dissolved or free oxygen, facilitated by microorganisms known as aerobes, to convert organic wastes into biomass and CO_2. In contrast, anaerobic processes necessitate the absence of oxygen in order to break down complex organic wastes into methane, CO_2, and H_2O through three essential stages: hydrolysis and acidogenesis (which includes acetogenesis and methanogenesis). Aerobic biological techniques are commonly used to treat organic wastewater in order to achieve a high level of treatment efficiency. On the contrary, significant advancements have been made in anaerobic biotechnology for waste treatment, which prioritizes resource recovery and usage while simultaneously accomplishing pollution control objectives [2].

The introduction of high-rate reactors, where biomass retention and liquid retention were not interdependent, marked a significant milestone in the development of anaerobic treatment [3]. UASB reactors have demonstrated significant efficacy when compared to alternative anaerobic wastewater treatment methods. These reactors have been used by various industries, including sugar, pulp and paper, dairy, chemical, potato starch, bean balancing, soft drink, fish processing, noodle processing, yeast production, slaughterhouse, and coffee processing, to manage their waste materials [3].

Anaerobic treatment systems (UASB) have several distinct advantages over aerobic technologies. These include a simple design, easy construction and maintenance, a small land footprint, low operating and construction expenses, minimal production of excess sludge, high resilience in terms of COD removal efficiency, ability to withstand fluctuations in temperature, pH, and influent concentration, quick recovery of biomass after shutdown, and energy generation [4].

The UASB is specifically engineered to purify wastewater by injecting it into the lower part of the reactor and allowing it to flow through a layer of biologically activated sludge, often in the form of granular aggregates. The particles of sludge aggregates demonstrate remarkable resilience and remain unclean even in real-world situations. When the wastewater comes into contact with the granules, the sludge aggregates provide a high level of treatment efficiency [3]. The process of internal mixing, which is promoted by the gases carbon dioxide and methane produced in anaerobic conditions, is crucial for the creation and upkeep of biological granules. However, some of the gas produced in the sludge blanket attaches to the granules. A gas-liquid-solid separator (GLSS) is installed at the top of the reactor to segregate the gas, liquid, and granules effectively. The purified water is discharged from the reactor once the gas-enclosed particles settle at the bottom of the degassing baffles and are reintroduced into the sludge blanket in GLSS [5].

Researchers have explored the use of conductive materials (CMs) as a means to enhance methane production in anaerobic digestion by supporting biofilm formation. Recent studies have shown that the application of CM can effectively enhance methane production while also mitigating other drawbacks associated with the process, such as longer start-up time and susceptibility to unfavorable conditions [6]. Different (CMs) have been used in anaerobic digestion to enhance the efficiency of biological methane production. These include carbon-based materials [7], iron-based materials [8], [9], mixtures of carbon and iron [10], as well as conductive polymers and iron-containing residues [11]. Most studies have shown that there is an elevation in methane production, elimination of organic matter, reduction in lag phase, and enhanced resilience to inhibitory circumstances.

The primary aim of this study is to Determine the factors affecting anaerobic wastewater treatment in batch experiments To enhance the UASB performance.

2. MATERIALS& METHODS

2.1. Wastewater Characteristics

The experimental reactors were installed and operated at the Suez Canal University veterinary experimental Farm in Ismailia, Egypt. The wastewater used was authentic buffalo effluent with varying properties. A fully submerged pump supplied the reactors with wastewater containing suspended particles. To reduce the fluctuation in flow rate, a reservoir with a fixed water level was erected before the reactors. Table 1 provides a concise overview of the attributes of the incoming wastewater.

Table 1. Influent wastewater characteristics.

Parameters	Mean Value
pH	7.6
BOD, mg/L	985
COD, mg/L	2050
TSS, mg/L	1388
TDS, mg/L	1060
NH_3 , mg/L	16.7
Alkalinity, mg/L	317
PO_4, mg/L	13
NO_3, mg/L	133

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NH_4, mg/L	17.7
EC, µS/cm	1154

2.2. Experimental design

We chose to conduct this statistical analysis using a factorial experimental design since it enables us to determine the impact of the variables with a small number of experiments. Biochar dose, Buffalo sludge dose, Supporting material, and pH concentrations received two values: a high value and a low value where was Biochar dose (2 and 20 g/L), Buffalo sludge dose (0 and 5 %), pH (5 and 8), and Type of supporting material (Rice straw, *Phragmites australis*, and Commercial activated carbon).

2.3. Preparation of biochar

Phragmites australis was collected from the Veterinary Experimental Farm of Suez Canal University in Ismailia, Egypt. Prior to drying, the precursor was cleansed using distilled water to eliminate dirt, water-soluble impurities, and debris sticking to the surface. The dried *P. australis* was subjected to sieving and crushing using a laboratory mill to get particles with dimensions ranging from 1 to 2 mm. Upon moving the compound to a pyrolysis reactor, it was subjected to a temperature of 550 °C. It was held at the temperature for one hour before being cooled to ambient temperature. After multiple rinses with purified water, the pH of the active substance reached a neutral level; it was dried in a vacuum oven at 110 °C overnight. Before storage, A dried sample of *P. australis* biochar (PABC) underwent a process of crushing and sieving to achieve a particle size of 200 mesh using conventional sieves (Model 200). Subsequently, the PABC was stored in a desiccator for future experimental use [12].

Rice straws were washed and chopped into 1-1.5 cm pieces. Subsequently, the material was subjected to a drying process in a prepared oven set at 110 °C for four hours. The material was subsequently heated for one hour at 400 °C in a pyrolysis reactor before being kept at 700 °C for one hour [13].

The commercial activated carbons were collected from Nice Chemicals Company (p) LTD (INDIA). Gas adsorption properties: - Dried Material absorbs about 20% of its weight of chloroform at 20 °C.

2.4. Sampling and Analytical Methods

Collected and tested were samples of the influent and effluents from the anaerobic reactors. The preparation of all samples, chemical solutions, and experiments involved the use of ultrapure water. The obtained influent samples were tested for various physio-chemical-biological parameters, including pH, COD, BOD, TDS, TSS, NH_3, and Alkalinity, using the stated procedures in "Standard Methods for the Examination of water and wastewater" American Public Health Association (APHA, 2017) [14].

The daily measurement of methane production will be conducted using the liquid displacement method, following the removal of CO_2 through adsorption into the KOH solution [15]. Duplicate samples were taken with a sampling time of 0.5 hours and a volume of 1 liter.

Both influent and effluent samples from the Upflow Anaerobic Sludge Blanket (UASB) were collected in sterile bottles and carefully shielded from direct sunlight during transportation. The samples were refrigerated at 4°C until analysis and promptly transported to Suez Canal University's Centre for Environmental Studies and Consultants in Ismailia, Egypt, for evaluation of specific criteria. The samples were tested within 4 hours from the moment of collection [16].

3. RESULTS&DISSCUSSION

3.1. Batch experiment

The experimental design employed in this investigation consisted of 24 batch experiments, as depicted in Figure 1. This experimental design aimed to examine the impacts of different factors through anaerobic batch trials. Furthermore, Table 2 displays the outcomes achieved in terms of the percentage of Chemical Oxygen Demand (COD) removal. The maximum removal of COD (85%) of Rice Straw Biochar (RSB) was at pH value, biochar dose, and inoculation concentration were equal to 8, 2 g/L, and 0%, respectively, in batch experiment 3. Commercial Activated Carbon (AC) has achieved maximum removal of COD (81%), and pH, biochar dose, and inoculation concentration were equal to 5, 2 g/L, and 0%, respectively, in batch experiment 1. The maximum removal of COD (83%) of *Phragmites australis* Biochar (PaB) was at pH, biochar dose, supporting Material, and inoculation concentration were equal to 5, 2 g/L, and 0%, respectively, batch experiment 12. Calculated as shown in the equation. 1,

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

Variable E represents the percentage of COD (Chemical Oxygen Demand) that is removed. COD_{in} refers to the initial concentration of COD in the influent, while COD_{ef} represents the final concentration of COD in the effluent, both measured in milligrams per liter (mg/L).

The statistical program Minitab 19 was used to estimate the average effect, main effects (impact of each variable), and two higher-order interactions on the answer.

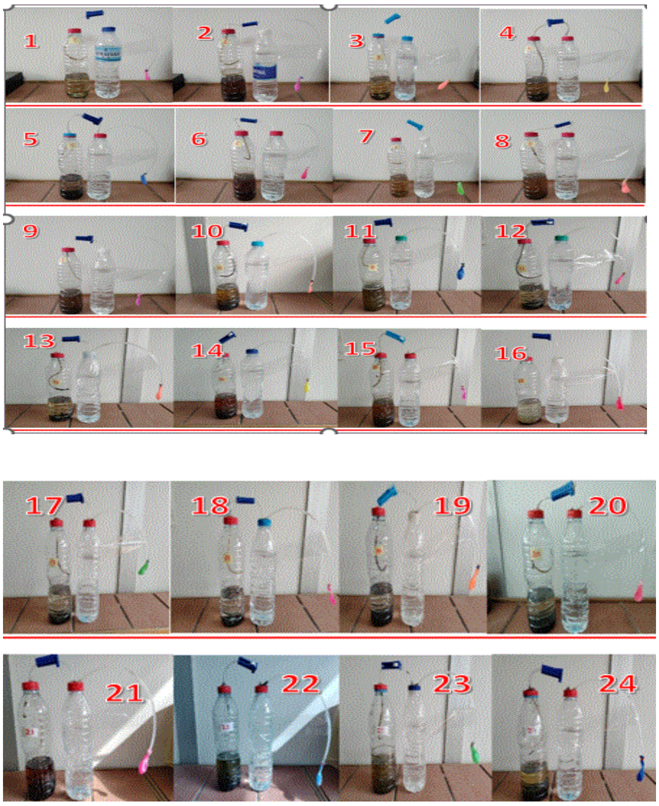

Fig. 1 Picture of batch digesters

Table 2. Full-factorial design matrix of four variables and results of COD removal.

Experiments	Biochar dose	Buffalo sludge dose	pH	Supporting material	COD removal (%)
1	2	0	5	AC	81 %
2	2	5	8	RSB	50 %
3	2	0	8	RSB	85 %
4	2	0	8	PaB	79 %
5	20	0	8	PaB	75 %
6	2	5	8	AC	80 %
7	2	0	8	AC	76 %
8	2	5	5	RSB	70 %
9	2	5	8	PaB	63 %
10	20	5	8	PaB	73 %
11	2	5	5	AC	66 %
12	2	0	5	PaB	83 %
13	2	0	5	RSB	74 %
14	20	5	8	RSB	64 %
15	2	5	5	PaB	73 %
16	20	5	5	AC	72 %
17	20	0	8	AC	55 %
18	20	0	5	AC	56 %
19	20	0	5	PaB	72 %
20	20	0	5	RSB	66 %
21	20	5	5	RSB	64 %
22	20	5	5	PaB	60 %
23	20	5	8	AC	57 %
24	20	0	8	RSB	55 %

3.2. Up-Flow Anaerobic Sludge Blanket Reactor

Once the batch experiment concludes, the continuous operation of the up-flow anaerobic sludge blanket (UASB) reactor will commence. There are two pilot-scale Upflow Anaerobic Sludge Blanket (UASB) reactors, as shown in **Fig.2**; this study will employ two pilot-scale UASB reactors. The reactors were fabricated using Polyvinyl chloride (PVC)

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cylinders that had a diameter of 10 cm and a height of 150 cm. One of the reactors (modified UASB reactor) will be utilized to examine the impact of supporting media usage. In contrast, the other (conventional UASB reactor) will be utilized to assess the influence of pre-treatment regarding the efficiency of the Upflow Anaerobic Sludge Blanket (UASB) reactors. By means of pumping, sewage will be moved from a ground storage tank to the reactors (submerged pump JET HVT-750F 1 HP). The flow rate will double from 35 to 70 L/d, resulting in a hydraulic retention time (HRT) ranging from four to eight hours. Based on the findings from the batch reactor. The reactor will receive rice straw biochar as a feedstock for anaerobic wastewater treatment.

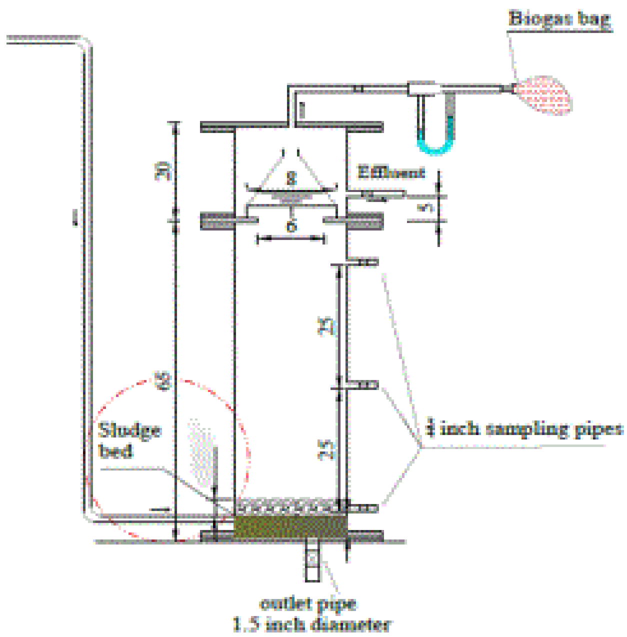

Fig. 2 Up Flow Anaerobic Sludge Blanket Reactor (UASB)

3.2.1 COD concentrations for Influent and Effluent of UASB reactor

The effluent and influent concentrations of COD from the UASB as shown in Figure 3. At the conventional reactor (without the inoculation), the concentration of COD in influent was 1400 mg/L,while the concentration of COD in effluent was 540 mg/L. On the other hand, at the modified reactor (with the inoculation), the concentration of COD in influent was 1375 mg/L,while the concentration of COD in effluent was 345 mg/L.

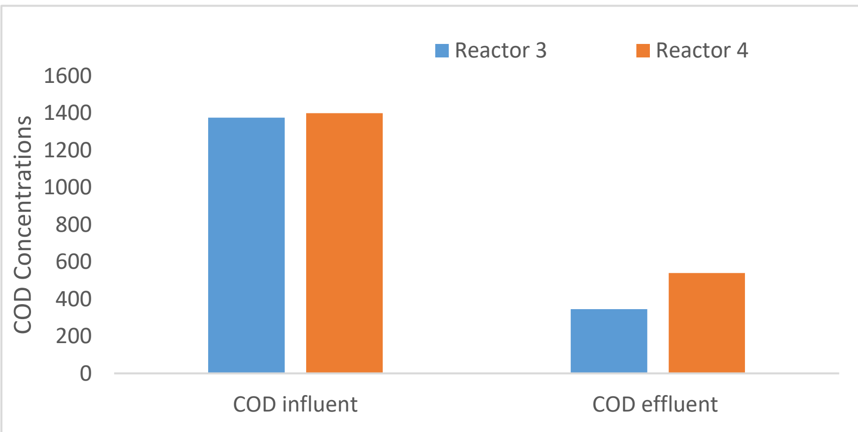

Fig. 3 Influent /Effluent COD concentrations

3.2.2 Color concentrations for Influent and Effluent of UASB reactor

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The effluent and influent concentrations of color from the UASB as shown in Figure 4. At the conventional reactor (without the inoculation), the concentration of color in influent was 185 PCU,while the concentration of color in effluent was 70 PCU. On the other hand, at the modified reactor (with the inoculation), the concentration of color in influent was 340 pcu,while the concentration of color effluent was 100 pcu.

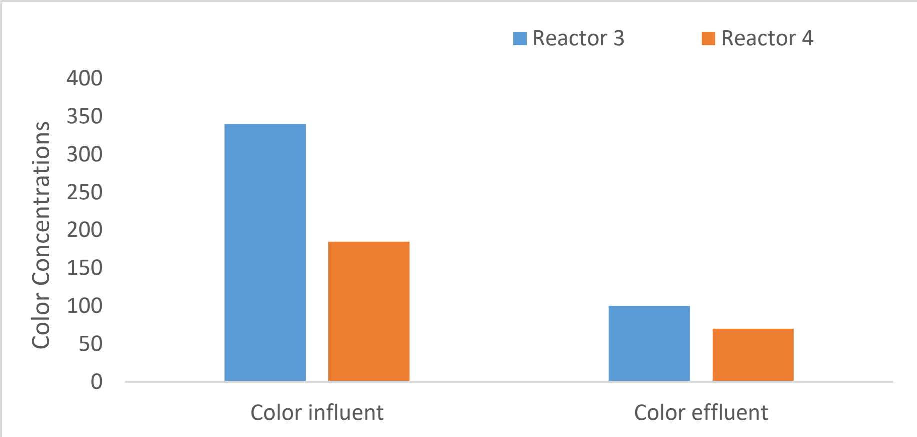

Fig. 4 Influent /Effluent COLOR concentrations

3.2.3 Turbidity concentrations for Influent and Effluent of UASB reactor

The effluent and influent concentrations of turbidity from the UASB as shown in Figure 5. At the conventional reactor (without the inoculation), the concentration of turbidity in influent was 90 NTU,while the concentration of turbidity in effluent was 50 NTU. On the other hand, at the modified reactor (with the inoculation), the concentration of turbidity in influent was 195 NTU,while the concentration of turbidity effluent was 52 NTU.

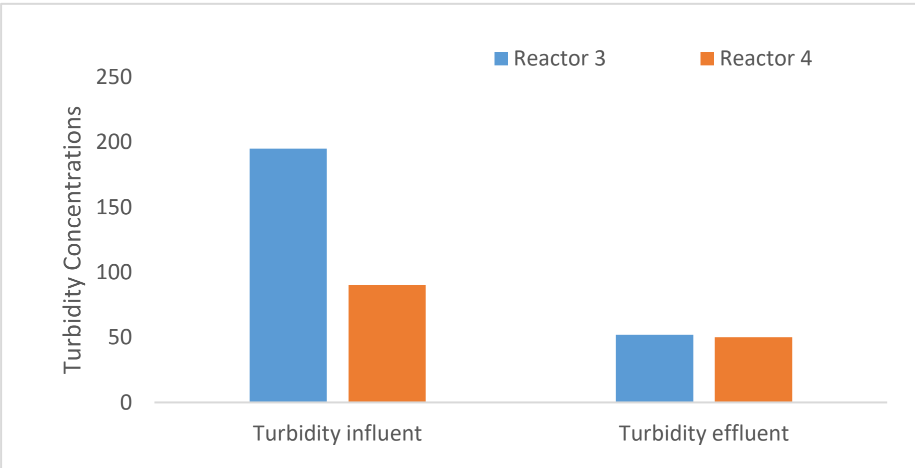

Fig. 5 Influent /Effluent Turbidity concentrations

4. CONCLUSION

According to the batch results, The maximum removal of COD (85%) of Rice Straw Biochar (RSB) was at pH value, biochar dose, and inoculation concentration were equal to 8, 2 g/L, and 0%, respectively in batch experiment 3. Hence, the batch study recommended using rice straw biochar for continuous UASB reactors.

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