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International Journal of Current Research
Vol. 10, Issue, 08, pp.72194-72197, August, 2018

INTERNATIONAL JOURNAL
OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

INVESTIGATION ON HYBRID UP-FLOW ANAEROBIC SLUDGE FIXED FILM (HUASFF) REACTOR FOR TREATING SAGO WASTEWATER

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ARTICLE INFO

Article History:
Received 20th May, 2018
Received in revised form
14th June, 2018
Accepted 25th July, 2018
Published online 30th August, 2018

Key Words:

Biogas, Chemical oxygen demand,
Sago wastewater, UASFF reactor.

ABSTRACT

This study evaluates the performance of Hybrid Up-Flow Anaerobic Sludge Fixed Film (HUASFF) reactor for treating sago wastewater. A laboratory scale HUASFF reactor having a volume of 30 litres was operated with Organic Loading Rate (OLR) of 0.55 kg COD/m^3/d. Several effluent characteristics such as pH, COD, TSS, VFA and biogas production were studied until steady state was reached. The pH of the feed in the reactor was comparatively stable which are well suited for methanogenic activities. The results revealed that variation of effluent pH (from 7.45 to 8.47) during the operation with respect to organic loading rate varied from 0.8723 to 4.2011 Kg COD/m^3.day with respect to following hydraulic retention time 4, 3, 2, 1.75 and 1.5 days.

Citation: ***Sheela, R. and Asha, B.*, 2018.** "Investigation on hybrid up-flow anaerobic sludge fixed film (Huasff) reactor for treating sago wastewater", *International Journal of Current Research*, 10, (08), 72194-72197.

INTRODUCTION

The chief producers of tapioca in India are Kerala, Tamilnadu and Andhrapradesh. They produced about 7 million tonnes of tapioca every year. On an average, the yield of sago is 200 kg per tonne of tapioca roots processed. This is a water consuming industry about 8000 litres of water is required to process one tonne of tapioca. About 30.000 to 40,000 litres of effluent is generated per tonne of sago production. The effluents are organic in nature with high polluting effects on environment. The sago and tapioca starch industry of Tamil Nadu is the result of scarcity created by the impossibility of imports of foreign sago and starch from Singapore, Malaysia, Holland, Japan and U.S.A., during Second World War. Sago and tapioca starch industry in Salem District and Tamil Nadu has had a phenomenal growth in the last 47 years. The industries like Sugar, Sago (Tapioca- based Starch) and Dairy are known for biodegradable waste streams. Such industries are water intensive with huge requirement of water for utilities like boiler and grey areas like washings, cleanings, etc,. The water reclamation from treating the effluent can be made to offset the requirement of virgin water by more than 50-70%. Hence, the available options of treatment require further modification to yield the best possible results of organic removal. In order to produce 1 ton of sago, 20 to 25 m^3 of water is used in sago industries in different unit operations such as washing the tuber, pulping and maceration. The waste generated from sago mills are bark "hampas" and wastewater. Generally the wastewater was acidic, high in organic load and low in nutrient. Starch extraction from sago pulp produces large amount of waste water. Depending on the capacity of the mill, almost 400 litres of wastewater and 12 kilograms of dry solids is generating from each log and for every kilograms of starch produce, approximately 20 litres wastewater is generated. Wastewater treatment consists of applying known technology to improve or upgrade the quality of a wastewater. The waste water can be treated by physical or chemical or biological process. A complete treatment system may consist of the application of a number of physical, chemical and biological processes to the wastewater. Physical methods include processes where no gross chemical or biological changes are carried out and strictly physical phenomena are used to improve or treat the wastewater. Examples would be coarse screening to remove larger entrained objects and sedimentation (or clarification). Chemical treatment consists of using some chemical reaction or reactions to improve the water quality. Probably the most commonly used chemical process is chlorination. Chlorine, a strong oxidizing chemical, is used to kill bacteria and to slow down the rate of decomposition of the wastewater. Bacterial kill is achieved when vital biological processes are affected by the chlorine. Another strong oxidizing agent that has also been used as an oxidizing disinfectant is ozone. Biological treatment methods use microorganisms, mostly bacteria, in the biochemical decomposition of wastewaters to stable end products.

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DOI: https://doi.org/10.24941/ijcr.31911.08.2018

More microorganisms, or sludge, are formed and a portion of the waste is converted to carbon dioxide, water and other end products. Generally, biological treatment methods can be divided into aerobic and anaerobic methods, based on availability of dissolved oxygen. Aerobic treatment processes take place in the presence of air and utilize those microorganisms (also called aerobes), which use molecular/free oxygen to assimilate organic impurities i.e. convert them in to carbon dioxide, water and biomass. The Anaerobic treatment processes, on other hand take place in the absence of air (and thus molecular/free oxygen) by those microorganisms (also called anaerobes) which do not require air (molecular/free oxygen) to assimilate organic impurities. The final products of organic assimilation in anaerobic treatment are methane and carbon dioxide gas and biomass. Anaerobic process is a biological process carried out in the absence of oxygen for the stabilization of organic materials by conversion to methane and inorganic end products such as carbon-dioxide and ammonia. The volumetric load (COD load per m^3 active volume per day) in an anaerobic reactor is typically 5 to 10 times higher than aerobic wastewater purification. Sludge growth in an anaerobic reactor is 4-5 times lower than in an aerobic system. If the anaerobic sludge is not fed, it will hibernate, which means longer periods without food can be spanned without excessive sludge mortality. The system will almost immediately become active after re-start. The encountered organic pollutant is converted into biogas with a high energetic value.

Najafpour *et al.,* (2006) studied the treatment of Palm oil mill effluent in upflow anaerobic sludge fixed film (UASFF) reactor with tabular flow behavior, to shorten the start up at low HRT. The reactor was operated at 38°C and HRT of 1.5 and 3 days and OLR was increased from 2.63 to 23.15 g CODS/L.d Granulation was observed within 20 days and the size of granules was reached to 2 mm. High COD removal efficiencies of 89 and 97% of HRT of 1.5 and 3 days were achieved respectively. A methane yield of 0.346 L CH4 /g COD removed when the highest OLR was obtained. The SVI at 15, 35 and 55 cm were 16.9 37.9 and 117 mL/.g respectively. Deshannavar *et al.,* (2012) designed a laboratory scale upflow anaerobic fixed-bed reactor (UAF-B) packed with polypropylene pall rings as packing media for treating dairy industry effluent. UAF-B was used to treat dairy effluent at a hydraulic retention time (HRT) of 12 hours and at different organic loading rates (OLRs). It was observed that chemical oxygen demand (COD), removal efficiency and biogas production rates increased with increase in OLR and the average COD removal efficiency of 87% and maximum biogas production of 9.8 l/d was achieved. The study clearly indicates that UAF-B was feasible to treat dairy industry wastewater. Nazila Samimi Tehrani *et al.,* (2015) stated that the hybrid system seems to be much faster than the conventional digester and even with up-flow anaerobic sludge bed. Treatability of the samples at various HRTs of 12, 24, 36 and 48 h was evaluated in the fabricated bioreactor. COD removal was examined at two different temperatures (24 and 40 °C). Maximum COD removal (80%) was obtained at HRT of 48 h, OLR of 25.85 g COD/Ld and constant temperature of 40 °C. Maximum biogas production was 2.40 (Ld) was obtained at HRT of 48 h, OLR of 32.60 (g COD/Ld) and constant temperature of 40 °C. Effluent pH was increased when HRT increased from 12 to 48 h. The optimum pH for anaerobic microbes was obtained at HRT of 48 h that it is shown a decreasing organic acid and increasing of COD removal. When bioreactor temperature increased from 24 to 40 °C, the COD removal and biogas production significantly increased. The conventional UASB reactor having long duration for start-up period but in the UASFF bioreactor with tubular flow behaviour having the short start-up period at low HRT (Najafpour 2008). The efficiency of hybrid reactor is more when compared to the conventional UASB reactor. The sludge blanket acted as a filter for removing the suspended solids from the wastewater and the major proportion of COD removal was due to the soluble and not suspended COD. The immobilization of the biomass in the support materials had an important role in reducing the influent COD because they created a good media for methanogenic bacteria on their surface (Seyyed *et al.,* 2015).

MATERIALS AND METHODS

The HUASFF reactor was made up of a plexi glass column with an internal diameter of 15 cm and a height of 180 cm. The total volume of the reactor was 30 litres and the working volume was 28 litres (excluding head space). The column consisted of three compartments; bottom, middle and top. The bottom part of the column, with a height of 111.4 cm was operated as a UASB reactor whereas the middle part of the column with a height of 40.2 cm was operated as a fixed film reactor. The top part of the bioreactor served as a gas–liquid–solid separator. The middle section of the column was packed with fujinospirals with the size of 26mm. The specific surface area of the packing material was 500 m^2/m^3 with a void space of 87%. The purpose of the top section (i.e. the gas–liquid–solid separator) of the reactor was to allow separation of the biogas and washed out solids from the liquid phase. An inverted funnel shaped gas separator was used to conduct the biogas to the gas collector tank. A gas sampling port was provided in the connecting tubing for the determination of biogas composition. The design features of HUASFF reactor is given in Table 1. The schematic diagram of Upflow Anaerobic Sludge Fixed Film Reactor is shown in Fig.1.

Fig. 1. Experimental Setup of Hybrid Up-flow Anaerobic Sludge Fixed Film Reactor

Table 1. Specification of HUASFF reactor

Description	Measurements
Total volume of the reactor, l	30
Total height of the reactor, cm	180
Effective height of the reactor, cm	168
Effective dia, cm	15
Dia of the reactor at top, cm	15
Dia of GLSS top and bottom, cm	3 & 12
Total height of the GLSS, cm	10
Dia of Influent & Effluent pipe, cm	1
Peristaltic pump	PP – 30 Model

Table 2. Physiochemical analysis of Sago wastewater

S.No	Parameters	Sample 1	Sample 2	Sample 3	Average value	Standard IS-10500
1.	pH	7.65	6.81	7.73	7.39	6.5 - 8.5
2.	Total solids, mg/l	1650	1800	1850	1766	2000
3.	Total suspended solids, mg/l	750	800	850	800	100
4.	Total dissolved solids, mg/l	900	1000	1000	966	500 -2000
5.	BOD @20□C, mg/l	1750	1850	1810	1803	30
6.	COD, mg/l	3100	3280	3150	3176	250
7.	Chlorides, mg/l	490	496	492	493	250 -1000
8.	Turbidity, NTU	95.0	97.0	98.0	96.6	1 - 5
9.	Phosphate ,mg/l	0.793	0.802	0.795	0.796	5.0
10.	Nitrate, mg/l	0.127	0.122	0.122	0.123	45-100
11.	Calcium, mg/l	30.10	30.55	31.20	30.61	75-200
12.	Lithium, mg/l	0.23	0.25	0.23	0.24	0.70
13.	Sodium, mg/l	64.13	65.01	64.57	64.57	20

In anaerobic reactor, the microbial support media is made from synthetic material, especially using polymers have been used predominantly at present PVC based support media is used. The PVC spiral packing media is commercially known as Fujino PVC spirals, comprises of numerous windings or S-shaped portions. The specific surface area of the above media is ten times more than the conventional media. Spirals permitted extremely high loading rates with high efficiency and provided significantly to the mass transfer performance. Fujinospirals is shown in the Fig. 2.

Fig.2. Fujinospirals

The experiment was carried out on two major operating parameters viz., influent flow rate and influent COD. The dependent variables of the operating parameters are hydraulic retention time and organic loading rate. The experiment was conducted with Sago effluent. The observations were made on operating the model on continuous mode for the following parameters Influent COD, mg/l, Effluent COD, mg/l and Volume of gas collection, m^3.

The experimental operating conditions and observations are correlated and interpretations on Hydraulic loading rate $m^3/m^2/$day, Organic loading rate, kg COD/m^2/day and Biogas generation, m^3 per kg COD removal were made to enumerate the performance of the model.

RESULTS AND DISCUSSION

Characteristics of raw sago effluent: The Characterization of sago effluent indicates that effluents are very acidic in nature and it is highly biodegradable because of its high organic content. The physiochemical parameters like pH, Total Suspended Solids, Total Dissolved Solids, Biological Oxygen demand, Chemical Oxygen Demand, Oil and Grease and Chlorides are presented in Table 2.

Startup Process

The start-up period is considered as the period taken for stable operation to be achieved. In addition, operating temperature is prominent during start-up. In this work, the treatment operation was carried out in the laboratory where the operating temperature varied from 25º C – 35º C (mesophilic range). The start-up stage of the process was began by continuous feeding of the reactor with an initial influent COD concentration of 480 mg/l with a HRT of 24 h and consequently organic loading rate of 0.551Kg COD/m^3/day which is remarkably a low value. The COD removal rate during first two days was low in the range of 30% to 40%. The low efficiency in removal at the beginning of the process is due to the biomass adaptation in the new environment. The reactor achieved at steady state conditions during the period of 7th day to 14th day with a COD removal efficiency of 90% (Fig. 3). It is difficult to maintain the effective number of useful microorganisms in the system (BAL *et al.,* 2001). The pH is an important factor to control the digestion process in the anaerobic reactors. The methane forming microorganisms can survive in a condition with pH values ranging between 6.6 and 7.6 (Ritmann and Mc cardy P.L 2001)., although stability may be achieved in the formation of methane over a range of 6.0 to 8.0. The pH values are interpreted with the organic loading rate and hydraulic retention time.

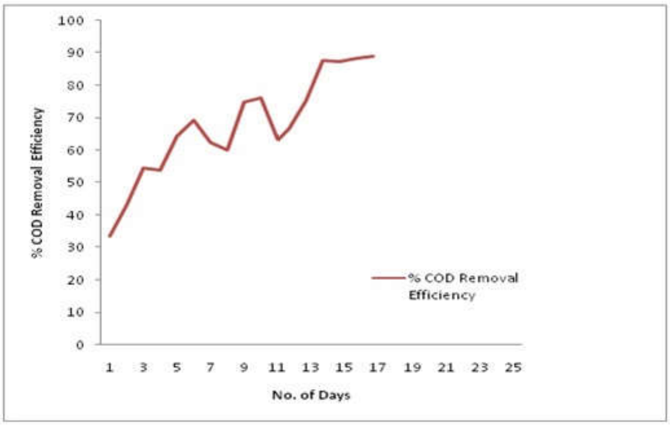

Fig. 3. Start up Performance of HUASFF reactor

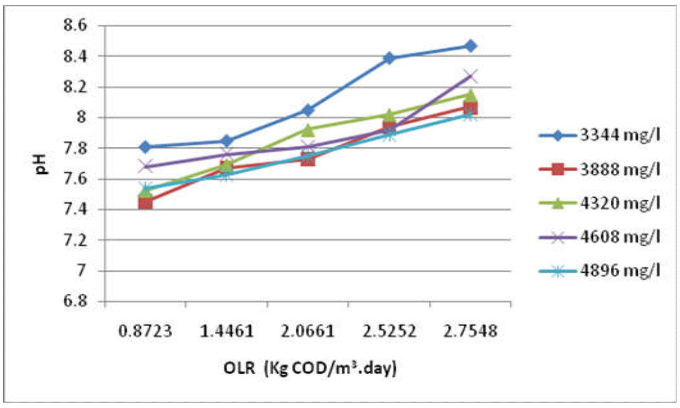

Fig. 4. OLR in Kg COD/m^3.day with respect to Effluent pH

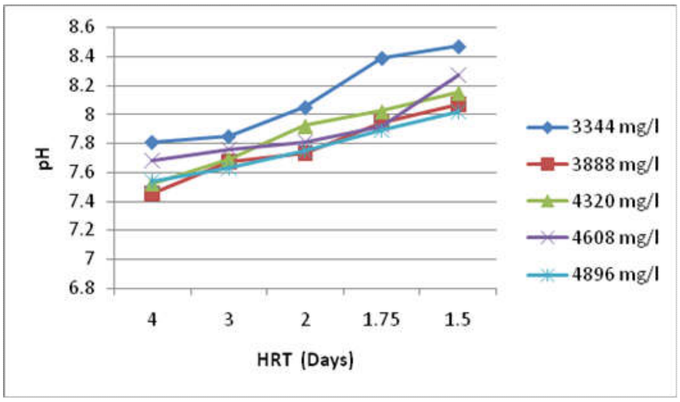

Fig. 5. HRT in days with respect to Effluent pH

The results are graphically presented in the Fig 4 to 5. Fig. 4 and 5 shows the variation of effluent pH during the operation with respect to organic loading rate and hydraulic retention time. The pH of the treated wastewater was ranged from 7.45 to 8.47, which indicates the buffering capacity of the reactor. In the case of with addition of co-digestion there was a sudden decline of pH from 8.47 at 1.5days HRT. It may be due to the addition of co-substrate. The declined level of pH in the period of operation proved that more volatile fatty acid was accumulated in the reactor.

Conclusion

Based on the experimental results and investigations, the performance of Hybrid Upflow Anaerobic Sludge Fixed Film Reactor (HUASFF) was evaluated. The following conclusions are arrived from the study:

- The reactor has attained a steady state for 7 to 14 days during start up.
- Variation of effluent pH (from 7.45 to 8.47)during the operation with respect to organic loading rate varied from 0.8723 to 4.2011 Kg COD/m^3.day with respect to following hydraulic retention time 4, 3, 2, 1.75 and 1.5 days.

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