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Performance of multiphase anaerobic hybrid reactor for the treatment of biopesticide wastewater

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Abstract: The major industries in the world are facing challenge in eliminating or decreasing the carbon footprint. The pioneer technological bioreactor, multiphase anaerobic hybrid reactor is identified as one of the high-rate anaerobic reactors that treat the high strength wastewater and simultaneously generate green energy biogas. In this investigation, experimentations on the performance of the multiphase anaerobic hybrid reactor were conducted for the treatment of neem based biopesticide wastewater uninterruptedly for 115 days at mesophilic temperature (30 - 35˚C). The research was carried out in three different stages based on the acclimatization, variation in loading and hydraulic retention time. By operating the multiphase anaerobic hybrid reactor at different the organic loading (OL) such as 4.0, 5.0, 6.5 and 7.6 kg COD/m3 at 24 h hydraulic retention time (HRT), it was found that 6.4 kg COD/m3 as the most apt for conducting the further experiments for attaining better reactor performance with 96.0 % COD removal efficiency. Moreover, it was also observed that the biogas production rate increased with increase in organic loading. The generation rate of biogas ranged from 2810 mL/d to 7020 mL/d. Thereafter, the HRT was decreased from 24 h to 12 h and to 6 h by maintaining the organic loading constant at about 6.4 kg COD/m3. Furthermore, an adaptive-network-based fuzzy inference system modelling was applied with the obtained experimental raw data and compared. It was found that there was one to one correlation between the modelling and the experimental results.

Keywords : Biopesticide wastewater, Bioenergy, Multiphase anaerobic hybrid reactor

1. INTRODUCTION

The fossil fuels are limited and found to be exhausted within the next 40 years (Kalak, 2023). Around four billion tons of oil resources are utilised per year. In order to guarantee energy security to future generations, the alternative energy resources that are ecofriendly and sustainable plays an important role. Bioenergy production from waste-to-energy is stated to have augmented from 221 TWh in 2010 to 283 TWh in 2022 (Kalak, 2023). The waste and wastewater from municipalities and industries with high organic load and other precious components could be used as a resource for the production of bioenergy through anaerobic treatment process (Kumar and Samadder 2020). The anaerobic process is superior than the aerobic since it uses less energy, has a simpler design and operation, and is more successful at producing biogas out of organic waste (Elreedy et al., 2016). It is a biological process in which microorganisms combine to break down and produce bioenergy out of organic materials in an oxygen-free environment. According to VenkateshKumar, Shanmugam and Veerappan (2020), a number of variables, including pH, temperature, inoculum, moisture content, volatile solids (VS), total solids (TS), and hydraulic retention time (HRT), affect the anaerobic generation of biogas.

The developing and developed nations have been shown to have fairly significant rates of crop loss due to pests (Pragati and Solanki, 2021). The pesticides eradicate weeds, pests, insects, which trigger disease in plants in agricultural settings. Insecticides, herbicides, fungicides, nematicides, and rodenticides are a few examples. Over time, the haphazard application of chemical pesticides has negatively impacted human health. The World Health Organisation (WHO) recently estimated that each year, over 25 million individuals in developing and undeveloped nations have acute occupational pesticide poisoning, and that there are also almost 20,000 fatalities globally (Vendan, 2016; Damalas and Koutroubas, 2018). An ecological biopesticide is of natural ingredients from sources such as plants, animals, and even microbes to control pests (Anamika, Sharma and Tyagi, 2019). In the entire process of agricultural development, the role of biopesticides has played an essential role in providing plant protection and improving the quality and productivity of crops (Manna et al., 2018; Sharma et al., 2019). There are now 410 biopesticide manufacturing facilities in India, of which 130 are privately held and 280 are government-owned (Chetan et al., 2019). Biopesticide, azadirachtin is produced using solvents like n-hexane and ethyl acetate. During the manufacturing of the azadirachtin, wastewater is mainly generated by extraction and solvent recovery process. The treatment of industrial biopesticide wastewater has received little attention to date, and no attempt has been made to use the multiphase anaerobic hybrid reactor (MAHR), according to a scan of all the material that is currently accessible. Because of its higher removal efficiencies for organic substrates, relationally simple architecture, and inexpensive capital and operational costs, MAHR has attracted a lot of interest in recent years (Mullai et al., 2011).

2. MATERIALS AND METHODS

2.1. Collection of sample

The wastewater was collected from phytopesticide manufacturing unit, Cuddalore, Tamil Nadu. The raw effluent collected was thoroughly mixed and the integrated sample was used for the study. All chemicals used were laboratory–grade reagents.

2.2. Multiphase anaerobic hybrid reactor (MAHR)

The multiphase anaerobic hybrid reactor used in this work was made from perpex tube with a volume of 5.0 L. The top third of the reactor was filled with spherical beads. At the lower part of the reactor an inlet was fixed. At the upper part of the reactor, above the packing column, outlet of the effluent was made. The outlet fixed on the topmost part of the reactor was meant for the flow of gas and gas flow meter was connected to it.

2.3. Experimental procedure

The wastewater was diluted with tap water to a desired concentration. The pH was adjusted to 7.2 –7.4 by adding sodium bicarbonate before feeding. The reactor was operated continuously for 115 days. The sample was collected and analysed at once. The flow rate, pH, alkalinity, acidity, COD and biogas production were recorded daily and analysed by following the standard procedures given by APHA (1995).

3. RESULTS AND DISCUSSION

3.1. Initial influent concentration

For first 25 days acclimatization and adaptation was carried out. From 26 to 89 days, the OLR was increased from around 4.0–7.6 kg COD $m^{-3}d^{-1}$, by increasing the influent concentration from around 4000 to 7600 mg COD/L, respectively, and keeping the HRT constant 24h. The COD removal efficiency which was higher (86.43%) on 25th day slashed to 31.73% on 26th day at the initial substrate concentration of 3999.8 mg COD/L. Thereafter, the COD removal efficiency gradually increased towards the end of this OLR and reached a steady state value of 82.65% (Table 1). The fall in COD removal efficiency at the beginning of this phase may be attributed to the curtailment of glucose and temporary stress caused on the biomass due to sudden change in feed concentration (Li et al. 2020). The possible reason for such a higher acidity value may be attributed to greater feed concentration of around the 7600 mg COD/l. According to Hou et al. (2022) increase in feed concentration leads to change in environmental condition within the reactor (Li et al. 2023). The steady state value of COD removal efficiency for the 5.0 and 6.4 kg COD $m^{-3}d^{-1}$ OLRs were 93.51 and 96.09% respectively (Table 1). When the OLR was augmented further to around 7.6 kg COD$m^{-3}d^{-1}$ by incrementing the substrate concentration to 7600 mg COD/l, the reactor performance declined and the COD removal efficiency fell to 57.77%. The decrease in COD removal efficiency might be due to substrate inhibition as reported by (Chai et al. 2021). So, initial substrate concentration around 6500 mg COD/L was considered as the optimum for attaining a better reactor operation. The production of biogas ranged from 2800 mL/d to 7000 mL/d.

Table 1: Steady state COD removal efficiency at different OLRs

(d)	(h)	(kg COD/ m^3d)	(%)
1-25	24	2.8	86.43
41	24	4.0	82.65
57	24	5.0	93.51
73	24	6.4	96.06
89	24	7.6	57.77
100	12	12.8	90.2
115	6	25.6	63.52

3.2. Hydraulic retention time

The OLR was increased from 12.8 to 25.6 kg COD $m^{-3}d^{-1}$ by reducing the HRT and maintaining the influent concentration constant closely around 6400 mg COD/L. At 12h HRT, the COD removal efficiency on the ninetieth day was 53.25%. As day passed on, the COD elimination effectiveness progressively rose and peaked at 90.20 percent on the hundredth day. When the HRT was reduced to 6 hours with an OLR of 25.6 kg COD m-3d-1, the COD removal efficiency had significantly decreased. The COD elimination efficiency increased with time and eventually reached a constant state of 63.52%. The effectiveness of COD elimination fell as HRT dropped. The lowering of HRT led to shorter residence time and resulted in little organic matter decomposition. Mullai et al. (2011) found a similar pattern of declining COD removal efficiency along with decline in hydraulic retention time. At 6 h HRT, the lowest ever COD removal efficiency of 63.52% was achieved on 115th day. This could be as a result of granular biomass disintegrating and washing away along with effluent due to higher flow rate (Mullai et al., 2011). This stage unequivocally proved that the MAHR employed in this investigation was capable of handling industrial phytopesticide effluent at the organic loading rate of 12.8 kg COD m-3d-1, with 90.20% COD elimination efficiency.

4. CONCLUSIONS

For the different influent concentrations, it was observed that 6500 mg COD/L reached higher reactor performance at 24h HRT. Furthermore, it was found out that the MAHR could treat phytopesticide wastewater effectively at the loading rate of 12.8 kg COD/ m^3d^1 at 12 h HRT with the COD removal percentage of 90.2%.

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