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RESEARCH ARTICLE

A COMPARATIVE STUDY ON TREATMENT OF CETP WASTEWATER USING SBR AND SBR-IFAS PROCESS

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ABSTRACT

The wastewater generated from industries needs to be treated before discharge but ETPs are not affordable and hence the common effluent treatment plant was provided for collectively treating wastewater from various industries. The existing treatment methods used for such wastewater are costly and hence the present study focusses on using biological method for treating pre-treated mixed industrial wastewater from CETP using a sequencing batch reactor (SBR) with suspended biomass and an SBR-IFAS, a combined suspended and attached growth process at an HRT of 10 hours. After treatment with SBR technology, the maximum COD removal efficiency obtained was 68.69% at an MLSS concentration of 2756 mg/L. Similarly, for the SBR-IFAS reactor, the COD removal efficiency reached 75.51% at an MLSS concentration of 2846 mg/L. MLVSS obtained was 1395.00 mg/L in SBR and 1433.00 mg/L in SBR-IFAS. Chromium removal reached 62.85% and 66.67% in SBR and SBR-IFAS reactors, respectively. The study revealed that the attached growth media and suspended growth media combinedly resulted in a higher reduction in industrial wastewater treatment and can ultimately help reduce the volume of the secondary treatment at CETP by increasing the footprint of the treatment plant.

KEYWORDS

Suspended growth, HRT, Ringlace, COD, Industrial wastewater

1. INTRODUCTION

Water resources are deteriorating due to their overuse in different sectors of life like domestic, industrial, agricultural etc. Most wastewaters contain pollutants that lead to eutrophication even after secondary treatment and when discharged into the river body (Moondra et al., 2021). Industries are one of the significant users of water sources and generators of wastewater. The major industries responsible for wastewater generation are dye, textile, pharmaceutical, paint, pesticides, fertilizer, caustic soda, dairy, brewery, distillery, inorganic chemicals, asbestos, petroleum, and other engineering industries (Mojiri et al., 2018). The effluents discharged through these industries need to be treated to meet the discharge limits. The greatest concern with small-scale industry is installing effluent treatment plants (ETP) to meet the discharge standards because of the unavailability of functional space, capital cost, technical workforce and operational cost (Nidheesh et al., 2020).

Hence to resolve these issues, CETP was constructed. CETPs provide adequate services to the industrial clusters to assist industries that lack enough resources to treat their effluents individually. The preliminary and primary treatment units are generally size-based separation units required for a basic clean-up of the industrial effluents. The effluent generated from the primary treatment units is unsuitable for discharge, and hence secondary and tertiary treatment is a must. The primary treatment units can remove the COD and solids over the range of 10–40%, depending on the influent characteristics and the applied technologies.

The secondary treatment process can reduce the COD, BOD and TSS up to 85–95% from the industrial influent. The tertiary treatment units are typically required to polish the effluent by eliminating toxic and hazardous contaminants to the desired levels (Ghumra et al., 2021). The present study was mainly focused on a comparative study of the performance of secondary treatment using Sequencing Batch Reactor (SBR) and Sequencing batch reactor combined with Integrated Fixed-Film Activated Sludge (SBR-IFAS) in treating the pre-treated industrial wastewater collected from a CETP of the urban industrial city of India.

2. MATERIALS AND METHODOLOGY

The study was conducted at a lab-scale in batch mode. Two reactors of 18 L capacity were used for the study. 15 L of CETP wastewater was added in both reactors, respectively. One reactor is a sequencing batch reactor (SBR), and another is an SBR with IFAS media, as shown in Figure 1. Ringlace media was used as IFAS strips. Five media of 14.5 cm height were inserted such that they remain suspended and fixed. Before starting the experiment, the reactors were aerated for 24 hours to acclimatize microorganisms to the new environment. External aeration was provided in both reactors. The effluent was collected after 10 hours of HRT (9 hours aeration followed by 1 hour of settling), and the supernatant was collected as effluent.

The parameters analyzed during the study for both influent and effluent were pH, Dissolved Oxygen (DO), mixed liquor suspended solids (MLSS), chemical oxygen demand (COD) and chromium; the parameters were analyzed according to standard procedure as per APHA 2012. The wastewater for the study was collected from CETP containing mixed industrial wastewater coming from 150 textile industries and 25 chemical industries. The wastewater collected from the CETP used for the present

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study has undergone primary treatment such as screening and coagulation using lime, PAC, polyelectrolyte etc. The initial characteristics of primary treated CETP wastewater is shown in Table1.

(a) (b)

Figure 1: Reactor setup (a) SBR (b) SBR-IFAS

Table 1: Initial characteristics of CETP wastewater

Wastewater Sample	pH	TSS (mg/L)	DO (mg/L)	COD (mg/L)	Chromium (mg/L)
Mixed industrial wastewater (textile + chemical)	7.6-8.3	516-1000	BDL	720-1200	0.3-0.42

The SBR-IFAS system is a combination of attached growth and suspended growth process. The IFAS media used is Ringlace media, which is suspended and fixed. Ringlace media is a flexible PVC rope type material attached as strands to the main rope. The strands contain loops that protrude out of them. Each loop has an approximate diameter of 5 mm, and aluminum frames were used to hold these media at the top and bottom of modules (Sen et al., 2006). Ringlace media is kept suspended in the wastewater even after decanting to maintain the healthy growth of biomass on the media. The attached growth on Ringlace media was analyzed through MLSS by oven drying method. For healthy growth of biomass, nutrient in the form of cow dung slurry was also added. The nutrient was added to maintain BOD:N:P in 100:5:1. Conventionally, the COD:N:P ratio for aerobic systems was reported to be 100:5:1 to ensure the presence of sufficient nutrient requirements for biomass growth ratio (Hamza et al., 2019).

3. Result and Discussion

3.1 Variation in pH

A decrease in pH was observed during the study in both the reactors, as illustrated in Figure 2. The pH for the pre-treated CETP wastewater (raw) ranged between 7.6 and 8.3. However, pH was slightly decreased for effluents in both IFAS and control reactor but was within the permissible limit. pH in SBR-IFAS was seen to be varying between 7.3 and 8.0, and for SBR, pH varied from 7.4 and 8.2.

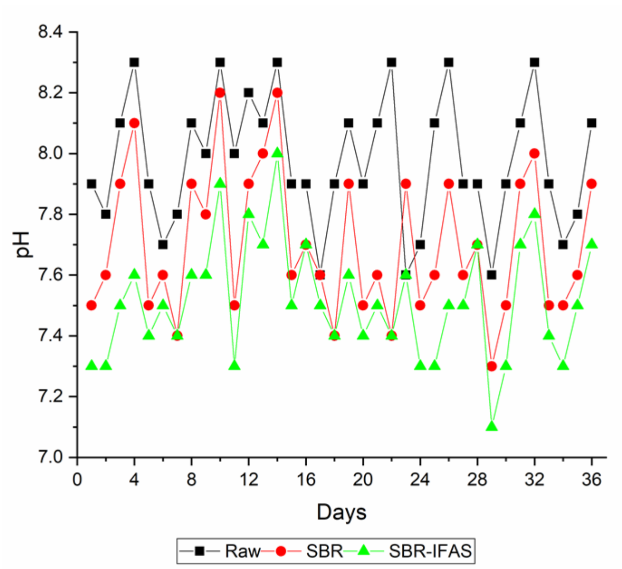

Figure 2: Variation in pH for raw and treated industrial wastewater

Wastewater treatment from the vegetable oil industry using honeycomb IFAS media reduced pH at 8 hours of HRT in aerobic systems. This validates that after aeration, the pH is likely to be reduced, which is the same as noted in the present study (Tehrani et al., 2018). The pH decrease may have occurred due to nitrification, alkalinity consumption, CO2 release, substrate depletion and organic matter bio-oxidation by decomposition of fermentation products in both suspended (SBR) as well as hybrid (SBR-IFAS) reactor (Ezechi et al., 2019). Researchers stated that pH near 7 leads to maximum removal in organics. In contrast, as pH shifts to the alkaline range, removal efficiency decreases for mixed industrial wastewater using electrocoagulnation process containing chemical, pharmaceutical, dying etc. (Tandel and Shah, 2017; Nidheesh et al., 2020).

3.2 Variation in DO

The presence of dissolved oxygen is mandatory for the effective working of aerobic organisms. The constant maintenance of DO in the range of 2-4 mg/L is necessary for the healthy growth of aerobic bacteria (Tehrani et al., 2018). DO concentration in the influent (primary treated CETP wastewater) was BDL. However, DO concentration in the effluents of SBR reached 2.6 mg/L, and for SBR-IFAS, it reached 2.4 mg/L, as shown in Figure 3. DO concentration was higher in the SBR-IFAS system during the initial days of the study. However, with the increase in MLSS concentration in the SBR-IFAS system. But by the end of the study, DO concentration was nearly similar in both the reactors.

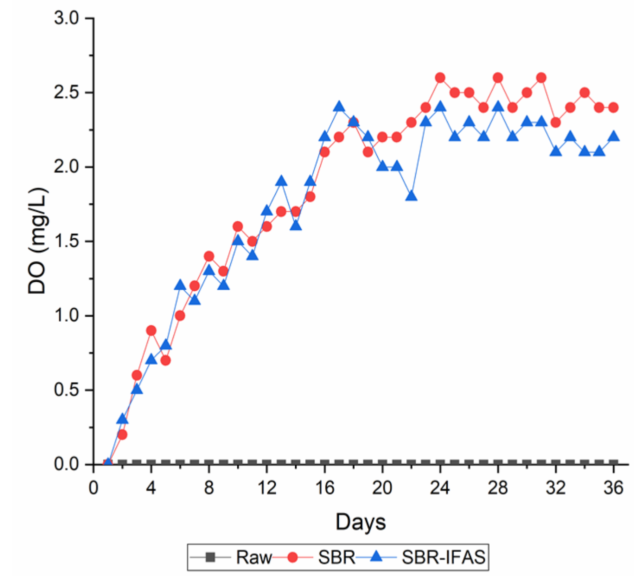

Figure 3: Variation in DO concentration for raw and treated industrial wastewater

3.3 Variation in COD

The influent COD of CETP wastewater ranged from 720 mg/L to 1240 mg/L. Huge variations were observed in the raw wastewater. Even with extreme variations in the CETP wastewater, the SBR-IFAS system was observed to remove COD concentration at such a lesser HRT effectively. COD removal efficiency reached 75.51% with a minimum COD concentration of 240 mg/L in the effluents of the SBR-IFAS system. However, for the control system (only SBR system), the maximum removal efficiency was 68.69%, with a minimum COD concentration of 360 mg/L, as shown in Figure 4. Higher COD removal was seen in the SBR-IFAS system compared to the control reactor (SBR) due to increased MLSS in the hybrid reactor. Apart from the suspended biomass, there was the growth of biomass on the ring lace media which also helps remove COD.

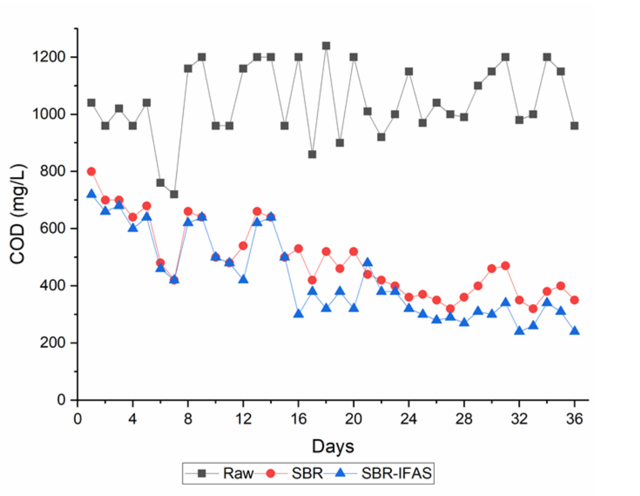

Figure 4: Variation in COD concentration for raw and treated industrial wastewater

The treatment of CETP wastewater by only biological treatment after pre-treatment may not give high removal efficiency. Due to the presence of dye components, the biomass may not remove the organic matter altogether. SBR with ringlace media also showed effective removal in brewery wastewater but at higher HRT (Ling and Lo, 1999). Various literature has been found various methods like coagulation, anaerobic and aerobic processes are used to treat CETP wastewater containing a mixed wastewater of textile, pigments and pharmaceutical effluents. A study on CETP wastewater containing pharmaceutical effluent was analyzed by aerobic oxidation; the study was carried out using extended aeration activated sludge process at three different MLSS concentrations of 2000 mg/L, 3000 mg/Land 4000 mg/L at an HRT of 5 days COD removal was 63%-78% with an increase in F/M ratio to 0.1 from 0.5 COD reduction was 78% with MLSS concentration of 4000 mg/L. HRT of 3.5 days COD reduction was 75% at an F/M ratio of 0.1 at 3000 mg/L of MLSS (Raj et al., 2004).

Honeycomb IFAS was used to treat effluent from the vegetable oil industry, after anaerobic treatment. It was seen that at an HRT of 8 hours removal efficiency of more than 90% was noted in COD; the removal efficiency is seen to be high because the wastewater is organic, which the aerobic bacteria can quickly degrade (Tehrani et al., 2018). In contrast, in the present study, the wastewater is mixed with textile and chemical wastewater, which has components that are not easily converted to simpler compounds. A study on the use of IFAS for COD removal from domestic wastewater showed that a maximum of 88% was noted at a maximum MLSS of 2100 mg/L after 30 days of operation of the reactor (Singh et al., 2015). In the present study, suspended MLSS was seen to be 2846 mg/L and gave a maximum COD removal of 75.51%. The removal efficiency in the present study may be low because the aerobic bacteria may not be very efficient in mixed industrial wastewater due to the presence of various other parameters like dye compared to the domestic wastewater. A higher HRT of a couple of weeks is required to treat CETP wastewater through anaerobic methods (Moosvi and Madamwar, 2007). In contrast, the same efficiency was observed in just 10 hours through the SBR-IFAS system as found during the study.

3.4 Variation in MLSS

The MLSS for the control reactor was seen to range from 604 to 2756 mg/L with a maximum VSS concentration of 1395 mg/L and in the IFAS reactor 704 mg/L to 2846 mg/L with a maximum VSS concentration of 1433 mg/L as shown in Figure 5. In the IFAS system, apart from the suspended biomass, attached biomass will also be present. The amount of biomass grown is 5.25 mg/m. It was seen that the IFAS strip had more MLSS, but the removal efficiency was not proportionately increased between the control (SBR) and SBR-IFAS reactor. This may be because the biomass grown on the strips may not be volatile, as the biomass grown inside may not be getting sufficient oxygen and food.

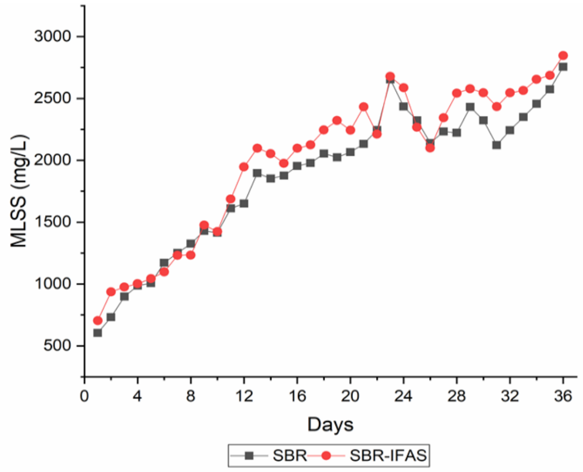

Figure 5: Variation in MLSS concentration for SBR and SBR-IFAS treated industrial wastewater

3.5 Variation in Chromium

Chromium removal was seen more in the IFAS-SBR reactor as the oxygen supplied is retained more by the IFAS reactor than SBR with suspended biomass. Chromium concentration was analyzed once a week. Inlet wastewater was seen to have Chromium in the range of 0.30-0.42 mg/L. The removal was seen to vary from 57.89% to 66.67% in the SBR-IFAS reactor, whereas, in the SBR reactor, it varied from 40% to 62.85%, as illustrated in Figure 6.

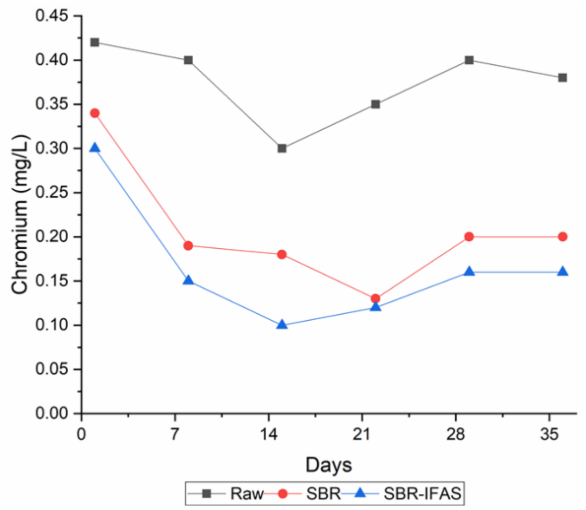

Figure 6: Variation in Chromium concentration for SBR and SBR-IFAS treated industrial wastewater

Heavy metals in biological treatment systems are seen to be removed by biosorption and bioaccumulation. This bioaccumulation occurs by the extracellular polymeric substances (EPS) content of suspended and attached microorganisms (Singh et al., 2015). Cr (VI) is highly soluble and is transported via the sulfate pathway across the cell membrane, finally reduced to Cr (III) in the cytoplasm of the microorganism. After that, Cr (III) interacts with protein and nucleic acids (Alam et al., 2020). Aeration is the significant factor for chromium removal. In addition to this, greater biomass led to higher removal efficiency (Vaiopoulou and Gikas, 2011). Researches have also revealed the neutral pH range enhances chromium removal (Mazumder and Goswami, 2015).

3.6 Sludge volume index (SVI)

SVI was also determined for both the reactors, as this factor represents the growth of biomass and ultimately states the functioning of a biological reactor (Sawyer et al., 2003). It was seen that SBR produced a sludge volume of 15 mL per 100 mL, thus giving an approximate sludge volume index (SVI) of 53 mL/gm, and for IFAS, a sludge volume of 25 mL per 100 mL maintaining an SVI of 90.71 mL/gm. The sludge volume index representing proper biomass growth for proper biological treatment should be 80 - 150 mL/gm; it shows that the IFAS reactor showed an SVI within the permissible limits. As per literature, SVI can vary from 30 to 400 mL/g. As a rule, a good SVI value, typically below 100 mL/g, is an indicator of the excellent settling properties of the sludge.

Therefore, keeping SVI below 100 mL/g is crucial for an activated sludge process (Chavez et al., 2019). As per the literature study on using IFAS for domestic wastewater treatment during the study, the SVI was maintained at a range of 42-130 and hence showing better settling characteristics (Singh et al., 2015), which is noticed even in the present study using mixed industrial wastewater thus affirming that the characteristics of industrial wastewater doesn't affect the settling characteristics in IFAS reactor but is not the case in SBR reactor because SVI was less than the required range. The aerobic bacteria on the media might be contributing to better settling property than the suspended bacteria.

4. Conclusion

The present study was conducted in a lab-scale batch mode. The study revealed that the IFAS when embedded in the SBR system, would improve the effluent quantity and help increase the footprint of the CETP. SBR-IFAS system removed 75.51% and 66.67% of organic matter, and Chromium from primary treated CETP wastewater having highly varied characteristics at a low HRT of 10 hours. Similarly, 68.69% and 62.85% organics and Chromium removal were obtained using the conventional system (SBR technology) for the same CETP wastewater. In addition to this, the SVI of the SBR-IFAS system (90.71 gm/mL) showed an excellent settling capacity signifying the SBR-IFAS system to be an efficient biological reactor in comparison to the SBR system (SVI = 53 mL/gm). Thus IFAS, if incorporated in the SBR system, would increase the effluent quality and lead to its safe disposal without harming the aquatic ecosystem.

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Data Availability Statement

All relevant data are included in the paper.

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