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A study on aerobic biodegradation of oil and grease containing wastewater

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Biological treatment of oily wastewater is troublesome owing to its complex nature on account of slowly biodegradable organic substances. Though aerobic biodegradation of oil and grease is substantially slow, but it can be improved by using well acclimatised biomass. In the present work, aerobic biodegradation of synthetic oily wastewater was studied by considering the removal of COD as well as oil and grease. The improvement in the biodegradation of aerobic biomass was observed during acclimation process which continued over a period of three months. During this period, synthetic dextrose as well as oil feed carrying adequate nitrogen and phosphorous source were added to the acclimation reactor. The quantity of synthetic oily wastewater was increased at the rate of 10 ml per batch run along with decrease at the rate of 10 ml in synthetic dextrose feed in a total feed of 100 ml volume in each batch run. The removal of COD was in the range of 64.4–85.4% and percentage removal of oil was observed to be between 54.6–80%. At dextrose to oil feed ratio of 10:90 and 60:40, the maximum degradation of oil and COD were observed respectively in the acclimation reactor. During addition of only synthetic oil feed with oil concentration more than 33.33 mg/L, inhibition was noticed which was overcome by addition of inorganic nutrients at a time interval of 48 h.

Keywords: Aerobic biodegradation, oily wastewater, acclimation process, oil removal, COD removal.

Introduction

One of the serious environmental problems at present is the generation of large amount of oily wastewater resulting from the anthropogenic activities[1]. Transport garages or workshops, petroleum oil filling and storage station, refineries, slaughter house and tannery, vegetable oil producing, food processing and many other industries are emerging sources for generation of a large amount of oily wastewater[2,3]. Oil and grease is the generic term which comprises petroleum hydrocarbons, phenolic compounds, vegetable and animal oil, surfactants, naphthenic acid, fatty acids etc.[4]. Biological process shall be useful to treat oil and grease containing wastewater due to its cost-effectiveness and comparatively eco-friendly nature[5] for which it is advocated to develop stable microbial active seed in biological oily wastewater treatment[6]. Azhdarpoor *et al.* (2014) reported that mixed microorganisms comprising bacteria, yeast, algae and fungi with their activities of enzymes can speed up oil degradation process[7]. It was also reported that acclimated sludge samples could be obtained rapidly in batch mode as longer residence time is necessary in continuous mode to achieve similar rate of degradation[8].

The concentration of hydrocarbon was observed to be decreased upto 65% with increase in the concentration of biomass in case of rotating biological contactor (RBC) unit[9]. Again, the removal of TPH (Total Petroleum Hydrocarbon), COD and oil and grease released from the oil field produced water using activated sludge process (ASP) was found to be more than 90% at 20 days sludge age (SRT) and 730 mg/L of MLSS[10]. At N:P ratio of about 19:1, 28.5:1, 38:1 as well as 47.4:1, removal efficiency was observed to be 98.6, 99.4, 99.4 and 99.3% respectively for TPH and 84.6, 97.8, 97.0 and 95.6% respectively for COD from hydrocarbon rich diesel oil by using green algae, cyanobacteria with bacterium *Burkholderia cepacia* in RBC[11]. In an aerobic batch reactor, removal of 85.1–97.1 % COD and 12.9–54.8% oil and grease was observed for the palm oil food industry wastewater[6]. The maximum COD removal efficiency was found to be

74.33% and 80% in ASP and Moving Bed Biofilm Reactor (MBBR) respectively in treating petrochemical wastewater[12]. The aim of the present work is to carry out the performance study of aerobic biodegradation for the treatment of synthetic oil and grease containing wastewater using acclimatized microbial sludge.

Experimental

Acclimation of biomass was done to make it compatible for treating synthetic oily wastewater under aerobic environment. For this process, two synthetic solutions i.e. dextrose feed of concentration 10,000 mg/L (C:N:P as 100:5:1) and oil feed of concentration 1000 mg/L (COD:N:P as 100:5:1) were prepared as per Table 1. The synthetic oily wastewater was prepared by mixing 1.11 mL of oil to 1 L distilled water.

Table 1. Composition of synthetic oil and dextrose carrying wastewater

Constituents in synthetic wastewater	Amount in oil bearing wastewater	Amount in dextrose bearing wastewater
Glucose	–	10 g/L
Oil (Castrol CRB prima diesel engine oil)	1.11 mL/L	–
Ammonium chloride (NH_4Cl)	0.1364 g/L	0.764 g/L
Potassium dihydrogen phosphate (KH_2PO_4)	0.0313 g/L	0.175 g/L

Soil samples were collected from three different petroleum waste disposal sites for obtaining naturally acclimated biomass. About 900 mL of supernatant was taken from settled soil suspension, 100 mL of dextrose solution and 500 mL biomass from an activated sludge reactor as being run in Environmental Engineering Laboratory, IIEST, Shibpur were transferred to the aerobic batch reactor of 5 L capacity PVC make container. The reactor content was diluted upto 3 L using tap water and aerated using two aquarium pumps. The acclimation process in batch mode was continued in ambient condition for a period of three months.

The acclimation feed added to the reactor with gradually decreasing synthetic dextrose solution and increasing amount of oil spiked wastewater at the rate of 10 mL per run starting from 90 mL dextrose feed and 10 mL synthetic oil feed solution. Along with the feed, the nutrient solution of magnesium sulphate, phosphate buffer, ferric chloride and calcium chloride of 1 mL each were added per litre of the reactor content in order to facilitate the growth of microbes. The pH of the aerobic reactor was maintained in the range of 7.2–8 by adding requisite amount of 1 N Na_2CO_3. The change in pH, MLSS and biodegradation of oil and grease as well as COD were regularly analysed during this period. All the necessary parameters were measured by Standard Methods (APHA)[13]. COD as well as oil and grease were estimated by closed reflux dichromate method and Soxhlet extraction method respectively after collecting samples followed by filtration. pH of the sample was measured using pH meter before filtration. MLSS was measured by filtering the sample and drying of commercial filter paper at 105°C. The values of specific oil degradation rate (SODR) for different runs were calculated using following formula and represented in Fig. 4.

$$SODR = (S_0 - S)/(T \times X) \quad (1)$$

where, S_0, S = initial and final concentration of oil and grease in mg/L, T = batch period in h and X = MLSS in mg/L.

Results and discussion

The results obtained from 11 sets of acclimation runs including synthetic dextrose feed (S1 in mL) and synthetic oil feed (S2 in mL) with varied combinations of S1:S2 as 90:10, 80:20, 70:30, 60:40, 50:50, 40:60, 30:70, 20:80, 10:90, 0:100, 0:110 are shown in Fig. 1 to Fig. 6. The 11th batch constituting of 110 ml oil feed was conducted for confirming the occurrence of inhibition due to increased oil loading. Variation of pH during acclimatization period was indicated in Fig. 1. pH remained in between 7–7.8 for first five runs and between 7.16–8.2 for next six runs. As pH was maintained under moderate alkaline range, it favoured acclimation[14]. Concentrations of oil content in reactor during treatment of wastewater carrying synthetic feed in different batches are shown in Fig. 2. Fig. 3 represented percentage oil removal in various batches during acclimatization. The percentage of oil removal was found to be in the range of 54.6–80%.

Fig. 4 shows the profile of SODR for various batches during acclimation (SODR values multiplied with 100 are represented against corresponding batch no). There was a case of maximum degradation of oil and grease in batch 9 and inhibition was noticed during addition of 33.33 mg/L of oil bearing synthetic feed in batch 10. SODR value was initially increased from batch 1–4 with lower concentration of oil and

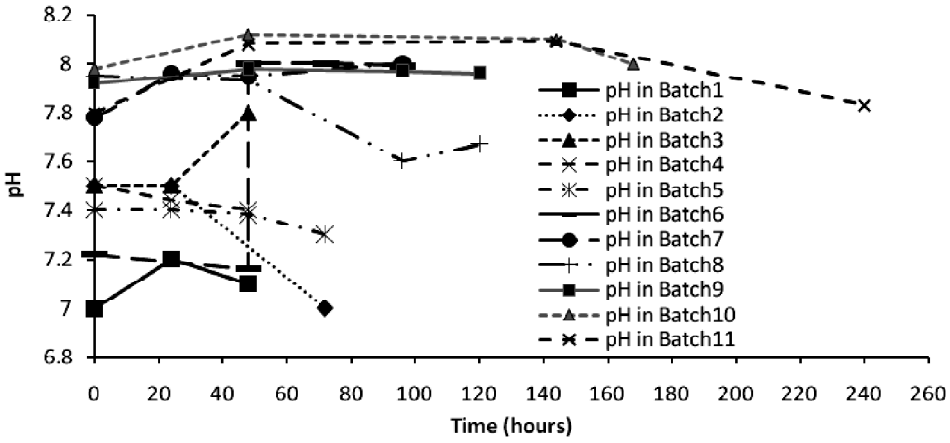

Fig. 1. Profile of pH for various dextrose to oil feed ratios.

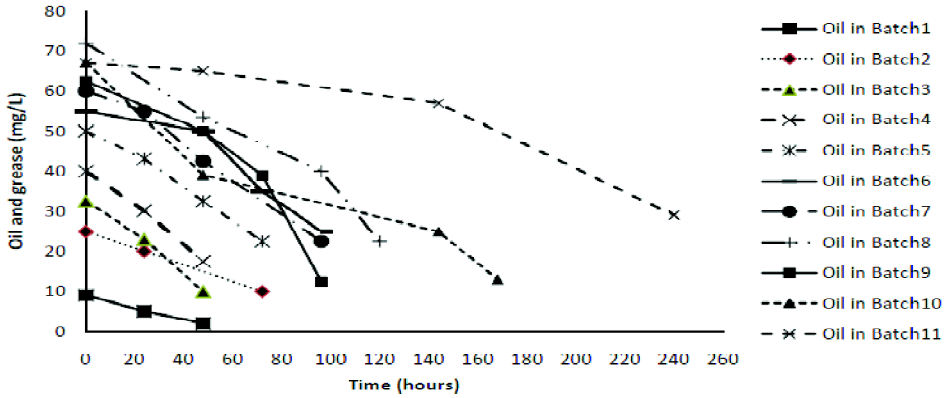

Fig. 2. Profile of oil and grease for various dextrose to oil feed ratios.

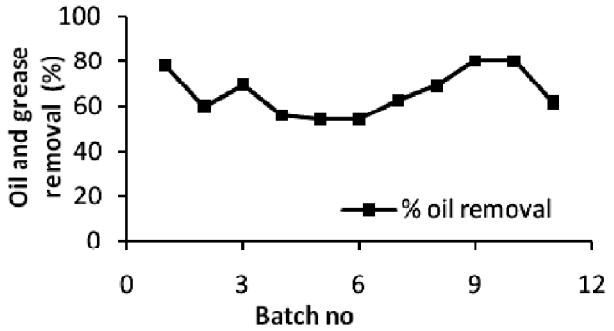

Fig. 3. Profile of oil and grease removal in percentage in various batches.

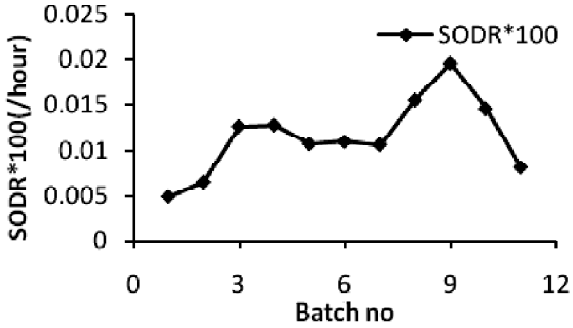

Fig. 4. Profile of specific oil degradation rate (SODR) for various batches.

then reduced from batch 4–7 probably due to increase in concentration of oil. To cope up with this gradual low SODR value, nutrients were added which resulted in increased SODR from batch 7–9. Another reason which can be attributed to this phenomenon is that biomass was more acclimatised with oil in this stage than previous batches. Again, the removal of COD was observed to be between 64.4 and 85.4% in 10 different batches during acclimatization and was only 38% in 11th batch as plotted in Fig. 5 and Fig. 6. Inhibition was noticed for addition of synthetic feed containing more than 33.33 mg/L of oil. Hence the batch period was enhanced and nutrients were added for improving the removal of oil and grease as well as COD.

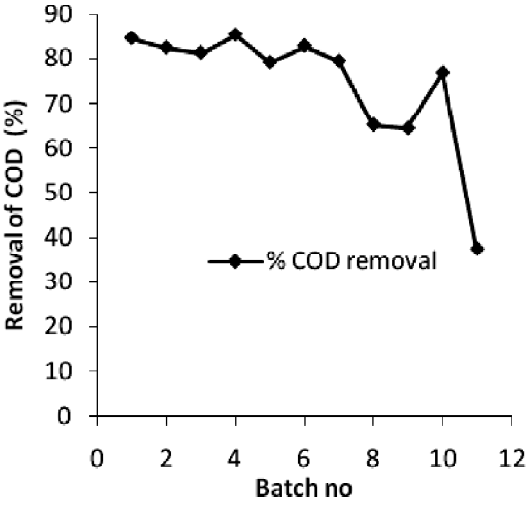

Fig. 5. Profile of COD removal in percentage in various batches.

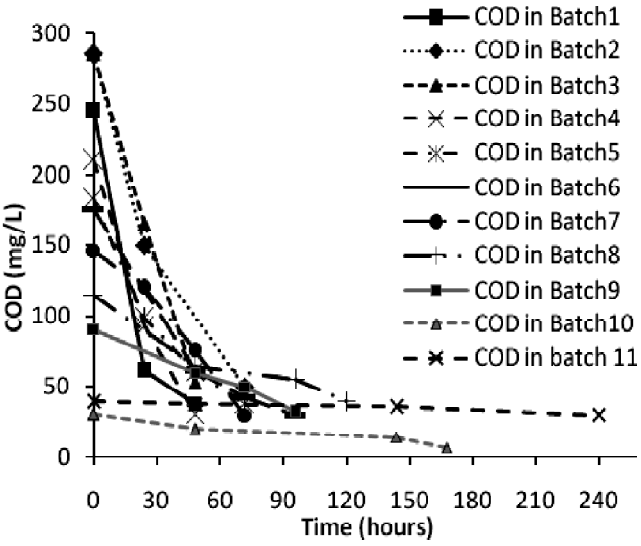

Fig. 6. Profile of COD for various dextrose to oil feed ratios.

The maximum removal of COD from petrochemical wastewater was found to be 74.33% in ASP which gradually decreased to 50.54% with increase in organic loading rate (OLR) from 1.09 to 2.09 kg COD/m^3day[12]. Initially the COD removal efficiency was increasing with the increase in input oil concentration and after reaching the highest removal efficiency of 74.33%, it started decreasing with increase in oil concentration. The removal efficiency of oil and grease and TPH were found to be 98–99% and of COD was found to be 92–97% from oil field produced water using activated sludge system at 20 days solids retention time[10]. Therefore, the results from present study corroborate with the earlier investigation.

Conclusions

Aerobic biodegradation of synthetic wastewater bearing oil and grease was investigated using batch type laboratory scale activated sludge reactor. It is observed that biomass acclimation could be possible by gradual increase in oil and grease concentration in wastewater. The COD removal efficiency was found to be in the range of 64.4–85.4% and oil and grease removal in the range of 54.6–80 % during initial 10 batches. Inhibition was observed for the batches with 100% addition of oil feed which was overcome by enhancing the batch period and adding required amount of nutrients.

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