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Possibility of treating rubber factory wastewater in biological reactors using media with low specific surface area

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Abstract

Four Covered Activated Ditch (CAD) type test reactors set with 25, 50, 75 and 100 m^2/m^3 specific surface areas (SSA) of Bio-brush were tested under 0.5, 1.0, 2.5 and 3.5 CODkg/m^3/d organic loading rates (OLR). Chemical Oxygen Demand (COD) of the treated effluent of each reactor were monitored to see the efficiency of treatment. In order to minimize the cost of a treatment system the main aim of this study is to investigate the possibility of treating rubber factory waste in CAD system with low SSA (<100 m^2/m^3) Bio-brush media. Although the cost of Bio-brush media with low SSA is less, the possibility of treating effluent with media below100 m^2/m^3 SSA in completely anaerobic treatment systems is not economical in terms of treatment efficiency. However, a CAD system with low SSA of Bio-brush media may be effectively used to remove COD (about 60-75%) with a final aerobic treatment part for removing remaining pollutants.

Key words: anaerobic, bio-brush, coir fibre, covered activated ditch, specific surface area, wastewater

Introduction

In Sri Lanka natural rubber industry is one of the most water polluting industries in the island. From an economical point of view biological treatment is considered the most suitable for rubber waste treatment when compared to extensive physical and chemical treatment methods. In addition, the treatment facility must be cost effective as raw rubber processing industries, are highly vulnerable to price fluctuations. Anaerobic treatment of waste is a simple and cost effective method of treatment, which can contribute significantly to the improvement of environmental standards in developing countries.

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As the loading capacity of an anaerobic reactor is not limited by the supply of any required reagent, such as oxygen in aerobic systems, in principle the loading potentials of anaerobic treatment systems are dictated by,

- the amount of viable sludge which can be retained under high loading conditions
- the contact between viable sludge and wastewater
- the rate of the biological conversion processes.

Specific surface area, porosity, low occupied volume, surface roughness, leaching of trace elements and the cost are among the main factors for the selection of the support media. According to Weiland & Rozzi, (1991) low cost per unit volume is one of the general requirements of an ideal support media

All modern high rate anaerobic treatment systems are based on some kind of sludge immobilization principle, in order to retain as much viable sludge as possible. They are mainly, attachment to stationary packing material or to particulate carrier material or bacterial sludge aggregation (Pol & Lettinga, 1986). Bio-brush media was developed to be used as a stationary media, specially in Anaerobic filter type CAD reactors.

Most of the media designed with high technology showing excellent biomass immobilization properties are often over weighed by high costs (Weiland & Rozzi, 1991; Tchobanoglous, G and Burton, F L (1991). Weiland & Rozzi, (1991) pointed that high cost for support media is a disadvantage of anaerobic filter reactors

The objective of this study, therefore was to investigate the possibility of treating rubber factory effluent with Bio-brush media at lower SSA (<100 m^2/m^3) in Covered Activated Ditches. Ultimate aim is to reduce the cost for media by reducing the amount of coir used for production of a unit volume of Bio-brush media.

Materials and Methods

Media design

The bristle fibre coir used in preparation of Bio-brushes was selected from a same batch in order to minimize variations. Mean surface area/unit weight of coir fibre used was 0.015 m^2/g coir. Coir fibre was cut in to 15 cm lengths for preparation of Bio-brushes with 15 cm diameters. Different amounts of coir fibre (weighed to get the correct SSA), was spread evenly in between two HDPE ropes (diameter 1.5mm) and using a special hand operated machine, twisted to get a bottle brush like flexible brush as explained by the Sri Lankan patent, No. 10951 (Warnakula, 1993). Different SSA tested with Bio-brush media were 25, 50, 75, 100 m^2/m^3.

Reactor design

Four identical ditch type test reactors (Fig. 1) were constructed with cement blocks, supported with concrete reinforcement. Length, width and depth of each reactor were 9.09 m, 0.3 m and

0.69 m respectively. Ditches were lined with a UV stabilized polyethylene sheet for waterproofing and were set with different SSAs of media. Bio-brushes were fixed in a vertical position and anchored to the bottom to prevent uplifting due to gas formation. The final effective volume of each ditch was 1.62 m^3.

Inoculum

Anaerobic biomass collected from a local crepe rubber factory wastewater treatment system was used for preparation of anaerobic seed sludge for test reactors.

Start-up of reactors

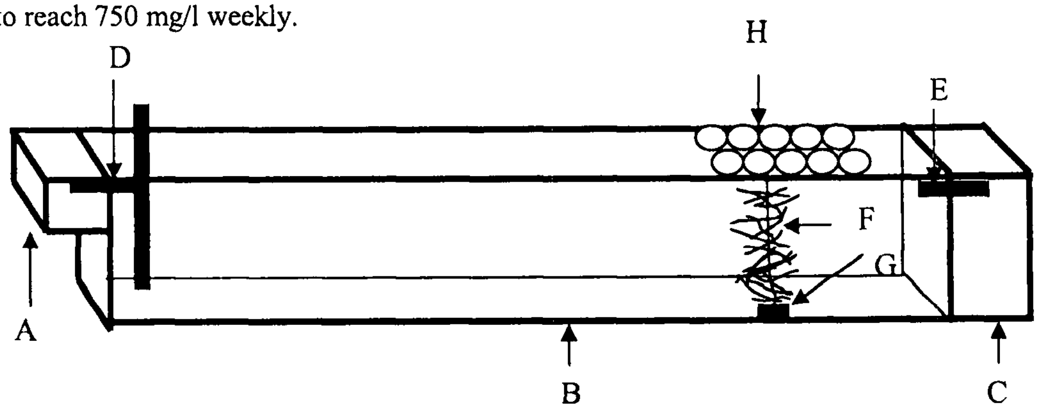
Reactors were filled with water and inoculated with 50 l of seed sludge mixture with 5000 mg/l of suspended solids content. Dilute rubber factory wastewater was introduced as the feed for a period of 2 weeks. COD of the feed increased gradually in 50 mg/l up to reach 750 mg/l weekly.

Feed characteristics and organic loading

Fresh rubber serum was used as the feed. The reactors were tested under four different organic loads; 0.5, 1.0, 2.5 and 3.5 CODkg/m^3/d. The retention time set was 2.66 days. Each organic load was introduced until the test reactors reached a steady state.

Analytical procedure

Samples were collected daily from each test reactor and tested for COD. Closed reflux colourimetric method (APHA, 5220D) was used to measure COD. pH of samples was measured daily using Jenway 3305 pH meter calibrated at pH 4 and pH 7. A photometric method (HACH 8006) was used to determine the suspended solids content. 25 ml, homogenized samples, collected daily were measured at 810nm using a DR/2010 HACH spectrophotometer.



A - Inlet chamber B - Test reactor C - Outlet chamber
D - Inlet pipe E - Outlet pipe F - Bio-brush
G - Weight H - Top view of a part of Bio-brush arrangement

Fig. 1. Schematic diagram of a test reactor (not to the proportion).

Results

Four different SSAs (25, 50, 75 and 100 m^2/m^3) were set with 15 cm diameter Bio-brush media were subjected to run under four different OLRs (0.5, 1.0, 2.5 and 3.5 CODkg $/m^3/d$).

Daily COD values of the effluent were measured in each reactor at each organic load until the reactor seems to coming to a steady state and the daily COD removal% of the reactors were evaluated associated with 3-day moving averages.

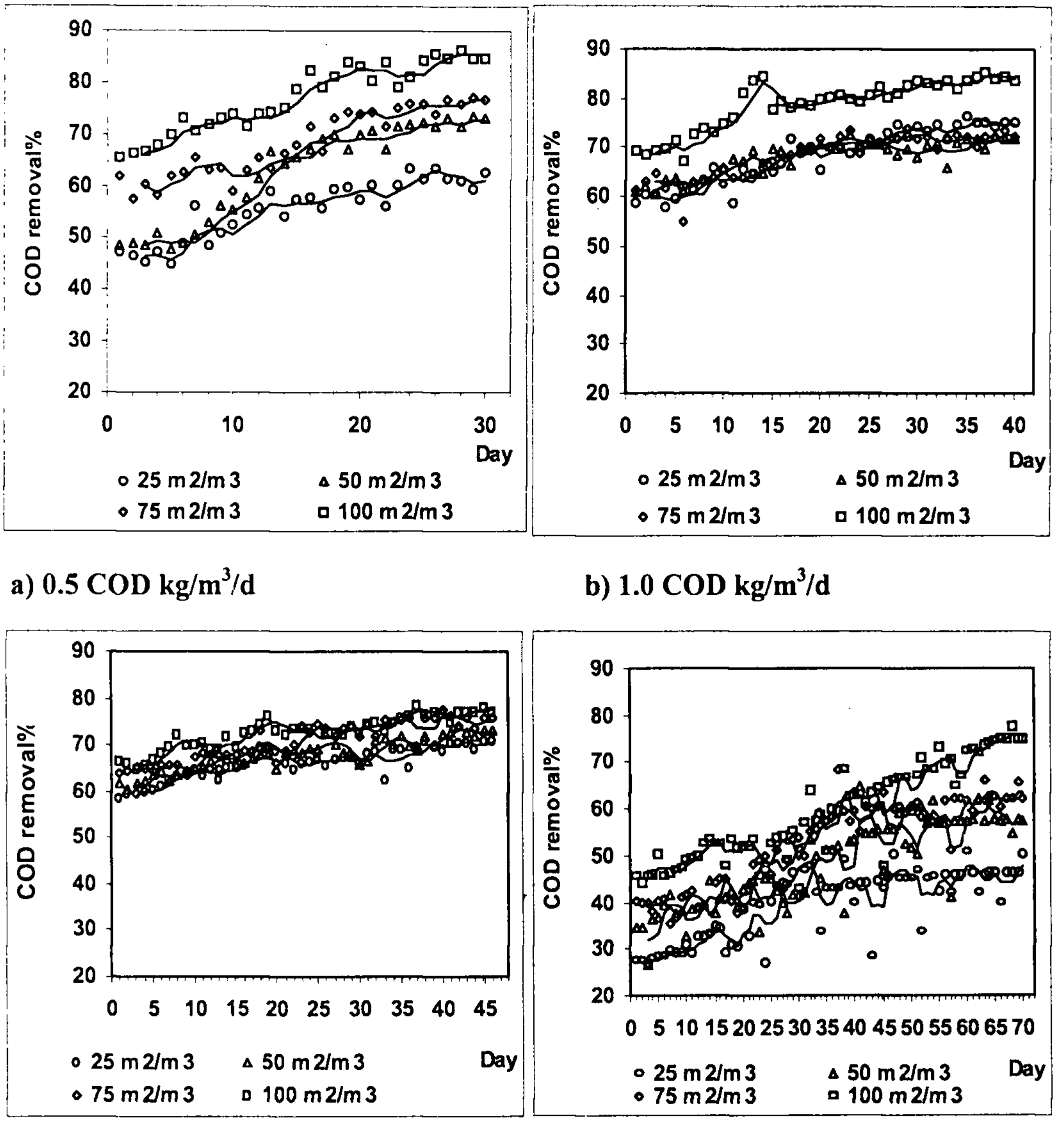
At the beginning of 0.5 CODkg/m^3/d OLR, the reactors with 25 and 50 m^2/m^3 SSA showed a COD removal% of below 50, while other two reactors showed an COD removal% above 50 while other two reactors showed a comparatively high COD removal%. In final 10 days of test period, all four test reactors showed their highest COD removal % and the reactors having higher SSA of media showed higher COD removal% at all the time (Fig. 2-a).

During the first five days run with 1.0 CODkg/m^3/d OLR the COD removal % in all four reactors did not show an increase in COD removal % and the COD removal % of all 4 reactors was above 50 % from the commencement (Fig. 2-b). From day 31 to 40 the increase of COD removal % was low.

From the beginning of 2.5 CODkg/m^3/d OLR, all four reactors showed a COD removal% above 55 (Fig. 2-c). Reactor with 100 m^2/m^3 SSA showed the highest COD removal % during the first half of the test period. In the second half of the test period reactors with 75 and 100 m^2/m^3 SSA showed a similarly higher COD removal % (Fig. 2-c).

At the beginning of 3.5 CODkg/m^3/d feeding rate, the COD removal % of all four reactors were below 50 and for about seven days, the increase of COD removal % in all four reactors were also very low (Fig. 2-d). Reactor with 100 m^2/m^3 SSA showed the highest COD removal% during the first thirty days of the test period. From day 30 to 45, reactors with 75 and 100 m^2/m^3 SSA showed a similar pattern in COD removal% and did not differ significantly. After day forty five the COD removal% of reactor with 100 m^2/m^3 SSA increased, achieving a removal of 75%, which was the highest. During the seventy days of test period, the COD removal % of reactor with 25 m^2/m^3 SSA was the lowest (Fig. 2-d).

In all four reactors the time taken to reach to a steady state increased with the OLR introduced.



a) 0.5 COD kg/m^3/d

b) 1.0 COD kg/m^3/d

c) 2.5 COD kg/m^3/d

d) COD kg/m^3/d

Fig. 2. COD removal% of the test reactors with different SSA under different OLRS

The analysis of variance carried out for the dependent variable COD removal efficiency, using the model with factors such as SSA and OLR was found to be significant at the probability level 0.001. The interaction effect; OLR × SSA and both the main effects were found to be significant at the probability level, 0.001.

During 0.5 CODkg/m^3/d OLR the COD removal efficiencies of different SSAs were significantly different to each other at probability level, 0.05. The highest COD removal efficiency was given by the reactor, set with highest SSA (100 m^2/m^3) of media followed by 75, 50 and 25 m^2/m^3. At 2.5 and 3.5 CODkg/m^3/d OLRs, COD removal efficiency showed the same sequence as 0.5 CODkg/m^3/d OLR. (Table 1, Fig. 3).

The pattern of COD removal efficiency showed by the above three OLRs deviated at 1.0 CODkg/m^3/d OLR. The highest COD removal efficiency was shown by 100 m^2/m^3 SSA of media and the second highest COD removal efficiency was shown by the reactor which was set with lowest SSA (25 m^2/m^3) of media. Both COD removal efficiencies observed at 100 and 25 m^2/m^3 SSAs were significantly different (P= 0.05). The COD removal efficiencies of reactors having 75 and 50 m^2/m^3 SSA were 71.95% and 70.86% (Table 1) and were the lowest values observed. They were not significantly different (P= 0.05) to each other (Fig. 3).

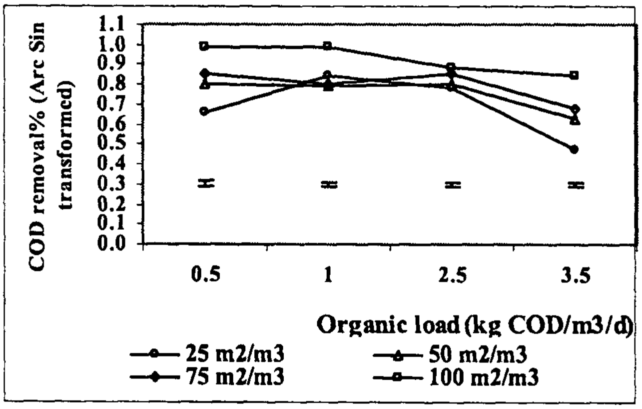


Fig. 3. Effect of different OLRs on COD removal efficiency under different SSA of media at maturation of the test reactors

Table 1. *Comparison of mean COD removal% for different SSA of Bio-brush media for fixed OLRs*

SSA (m^2/m^3)	OLR (CODkg/m^3/d)			
	0.5	1.0	2.5	3.5
25	60.99^D	74.73^B	70.15^D	45.57^D
50	71.56^C	70.86^C	72.02^C	58.28^C
75	75.31^B	71.95^C	75.00^D	62.57^B
100	83.54^A	83.67^A	77.06^A	74.55^A

(Means with the same letter are not significantly different at P=0.05 using DMRT)

Discussion

Four (25, 50, 75 and 100 m^2/m^3) different SSA of media, were set with 15cm diameter Bio-brush media respectively and the effectiveness of treating crepe rubber factory effluent under four different OLRs (0.5, 1.0, 2.5 and 3.5 CODkg/m^3/d) was tested. COD removal efficiency was found to increase with increasing SSA of media under all four OLRs tested. By increasing the amount of coir, the SSA of Bio-brush media can be increased. With this increasing SSA, Bio-brush media increases its ability to maintain a favourable amount of entrapped and attached biomass, which directly affects the performance of the reactor favourably (Iza, *et al.*, 1991; Young, 1991). This is the main reason for increasing the COD removal% with increasing SSA of media. By accumulating and entrapping large amounts of micro-organisms on inert support media the solid retention time could be increased and this leads to a high performance in biological reactors (Kenedy & Droste, 1991). The SSA of the media used in full-scale anaerobic filters averages about 100 m^2/m^3 regardless of the type of media (Young, 1991).

Results from the studies of Young & Dahab (1983) using corrugated modular blocks of different sizes and shapes, indicated that media with a high capacity to entrap and prevent the washout of the biomass from the reactor, is more important than the SSA of media. Although the cost of Bio-brush media with low SSA is less, the possibility of treating effluent with media below 100 m^2/m^3 SSA in completely anaerobic treatment systems is not economical in terms of treatment efficiency. However a CAD system with low SSA of Bio-brush media may be effectively used to remove COD (about 60-75%) with a final aerobic treatment part for removing the remaining pollutants.

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