

Effect of Bio-brush medium: a coir fibre based biomass retainer on treatment efficiency of an anaerobic filter type reactor

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Abstract

Five Covered Activated Ditch (CAD) type test reactors set with five different specific surface areas (SSA) of Bio-brush were tested under four organic loading rates (OLR). Chemical Oxygen Demand (COD), reactor pH and suspended solids (SS) of the effluent of reactor with 200 m²/m³ were monitored.

The efficiency of treatment increased with increasing SSA of media. On the basis of its performance the combination of Bio-brush media with 200 m²/m³ SSA under 1.0 COD kg/m³/d OLR was selected as the best for CAD reactors and the average COD removal achieved was about 89%. Under this OLR, correction of pH could be avoided for an efficient treatment. Reactors with higher SSA of media were able to tolerate organic shock loads comparatively.

No special cycles were observed in removing biomass from the test reactor under any of the four OLRs. During maturation COD, pH and SS of treated effluent with 200 m²/m³ SSA were about 100 mg/l, 6.7 - 7.2 and 26 - 43 mg/l respectively which were below the maximum desirable levels stipulated by the Central Environmental Authority.

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

Introduction

Sri Lanka produces about 100 million kg of natural rubber per year, discharging approximately 18 million kg of COD annually to the environment. In most factories effluent is discharged directly to a near by natural water

stream causing serious environmental problems. Conventional treatment systems like pond or lagoon system used by some factories in early 70^s had the inherent disadvantage that they required large areas of land, which was not available in most factory sites,

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although they were inexpensive and simple in operation.

Aerobic treatment methods such as activated sludge process, oxidation ditch process and rotating biological contactors are quite effective in removing pollutants but considered very expensive in relation to anticipated profits from the natural rubber industry. Aerobic systems inherently use extensive energy for providing oxygen to the system and hence cost more.

Anaerobic methods are not energy extensive and they mainly convert biodegradable organic matter into methane, CO₂ and water. Recent developments in the digester design and recent advances in the understanding of the microbiology of the process have significantly improved the potential use of anaerobic methods for industrial wastewater treatment.

Maintenance of an adequate amount of active biomass has been described as a key factor to a safe and stable operation (Metcalf & Eddy, 1991; Young, 1991). For retention of high concentration of active biomass, immobilization on inert support media has been reported to be very effective (Aivasidis & Wandrey, 1988; Kennedy & Droste, 1991). Coir has been identified as a suitable raw material for producing such a media (Warnakula, 1993) with excellent surface properties (Bath *et al.*, 1973; Bhowmick & Debnath, 1984; Kulkarni *et al.*, 1981) that favours immobilization of biomass. This new medium; Bio-brush is known to accelerate the low cost pond process.

This new process known as Covered Activated Ditch (CAD) system is a cost effective high rate treatment system in addition to drastic size reduction in the pond (Warnakula, 1996).

Preliminary studies have shown that treatment efficiency of CAD system could be optimized by changing the packing strategy of Bio-brush medium. However this has not been fully investigated. Because of the growing demand for CAD system for wastewater treatment, systematic exploration of the possibility of optimization has become a priority area for investigation.

The objective of this study, therefore was to investigate the effect of different packing strategies of Bio-brush media in Covered Activated Ditches on treatment efficiency with a view to optimizing it with special reference to safe and stable long term operation and acceptable quality of treated effluent.

Materials and Methods

Media design

The bristle fibre coir used in preparation of Bio-brushes was selected from the same batch in order to minimize variations. Mean surface area/unit weight of coir fibre used was 0.015 m²/g coir. Coir fibre was cut into 10 cm lengths for preparation of Bio-brushes with 10 cm diameters. Using different amounts of coir fibre, Bio-brushes were prepared to give 50, 100, 150, 200 and 250 m²/m³ SSA as explained by the Sri Lankan Patent, No. 10951 (Warnakula, 1993).

Reactor design

Five 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 m³.

Inoculum

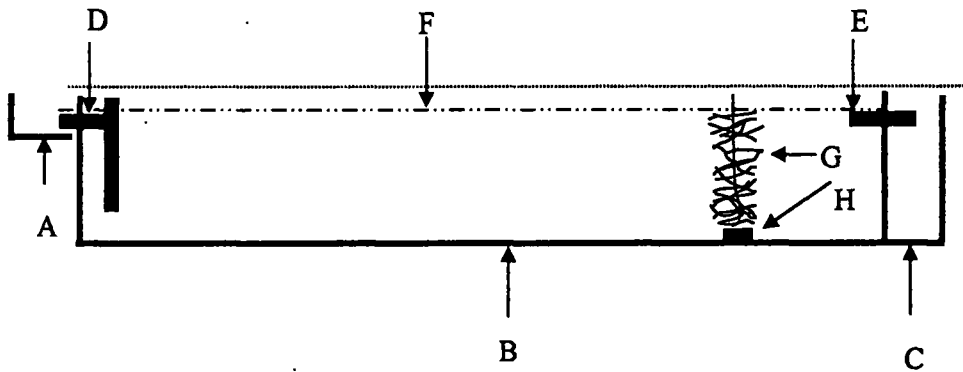
Anaerobic biomass collected from a local crepe rubber factory wastewater treatment system was used for preparation of anaerobic seed sludge for test reactors.

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/m³/d. The retention time set was 2.66 days. Each organic load was introduced until the test reactors reached a steady state.



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|-------------------|------------------|-----------------------------|
| A - Inlet chamber | B - Test reactor | C - Outlet chamber |
| D - Inlet pipe | E - Outlet pipe | F - Coir-based odour filter |
| G - Bio-brush | H - Weight | |

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

Bio-brush medium on efficiency of CAD reactor

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.

Results and Discussion

By increasing the amount of coir, the SSA of Bio-brush media was increased. In the reactors with five (50, 100, 150, 200, 250 m^2/m^3) different SSA of media, the COD removal

efficiency was found to increase with increasing SSA of media under all four OLRs (0.5, 1.0, 2.5 and 3.5 $\text{CODkg}/\text{m}^3/\text{d}$) tested (Fig. 2). Due to its brush type configuration Bio-brush media is highly capable in entrapping biomass. By accumulating and entrapping large amounts of microorganisms 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 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 0.001 probability level. The interaction effect; $\text{SSA} \times \text{OLR}$ and both the main effects were also found to be significant at the probability level of 0.001.

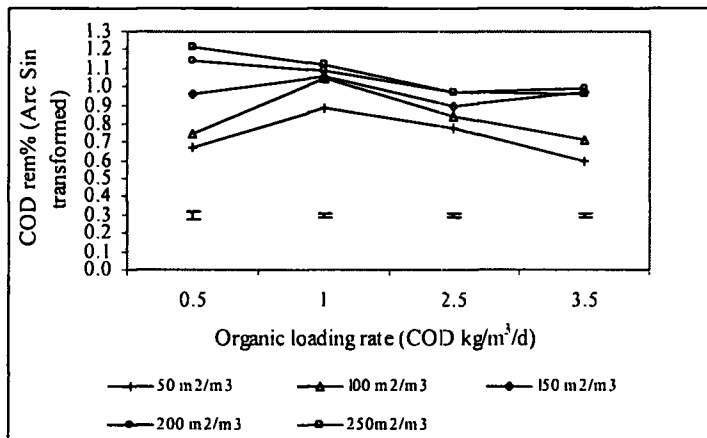


Fig. 2. Effect of different OLRs on COD removal efficiency under different SSA of Bio-brush media

Reactors with higher SSA ($>100 \text{ m}^2/\text{m}^3$) showed comparatively higher COD removal% than the reactors with lower SSA ($<100 \text{ m}^2/\text{m}^3$). Under all four OLRs tested reactors with 200 and $250 \text{ m}^2/\text{m}^3$ SSA of media performed well (Fig. 2). At higher OLRs (2.5 and $3.5 \text{ CODkg}/\text{m}^3/\text{d}$) the COD removal% of the reactors with higher SSA of media did not show a significant difference to each other at 0.05 probability level.

Even the highest values of COD removal% (91% and 94% respectively) was observed during the run under 0.5 $\text{CODkg}/\text{m}^3/\text{d}$ OLR (Fig. 3), this OLR is too low and not economically feasible for treating factory effluents with high hydraulic volume. Reactor with $250 \text{ m}^2/\text{m}^3$ SSA run under $1.0 \text{ CODkg}/\text{m}^3/\text{d}$ OLR, showed 90% of COD removal, but in long-term operation there is a high possibility of clogging the reactor as coir is densely packed in media to

give the particular SSA. The combination of Bio-brush media with $200 \text{ m}^2/\text{m}^3$ SSA under $1.0 \text{ CODkg}/\text{m}^3/\text{d}$ OLR showed a mean removal of COD about 89% (Fig. 3) which was quite feasible in wastewater treatment.

During the run with $3.5 \text{ CODkg}/\text{m}^3/\text{d}$ OLR reactor with $150 \text{ m}^2/\text{m}^3$ SSA achieved about 82% of COD removal (Fig. 3). When reducing the OLR from 3.5 to $1.0 \text{ CODkg}/\text{m}^3/\text{d}$ the COD removal increased only by 5% in the reactor with $150 \text{ m}^2/\text{m}^3$ SSA. But reactors with lower SSA of media were highly sensitive to the OLR. The COD removal decreased by 20% in the reactor with $100 \text{ m}^2/\text{m}^3$ SSA when the OLR was increased from 1.0 to $3.5 \text{ CODkg}/\text{m}^3/\text{d}$. These observations show that the reactors with high SSA of media can tolerate organic shock loads, than the reactors with low SSA of media.

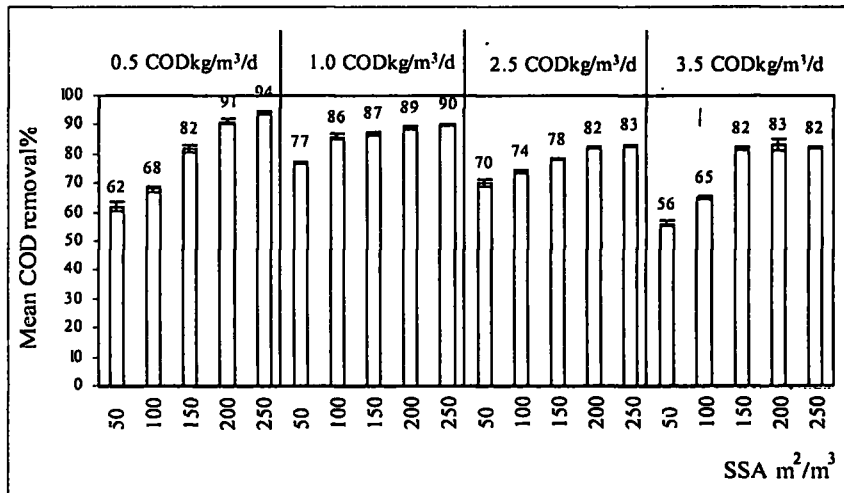


Fig. 3. Mean COD removal% of test reactors at maturation under four OLRs

Bio-brush medium on efficiency of CAD reactor

The SSA of the media used in full-scale anaerobic filters averages about $100 \text{ m}^2/\text{m}^3$ regardless of the type of media (Young, 1991). Results of this investigation reveal the possibility of increasing the COD removal efficiency by increasing the SSA of Bio-brush beyond $100 \text{ m}^2/\text{m}^3$ (Fig. 2 & 3). Specially in high OLRs, the COD removal efficiency increased significantly with Bio-brush media set with higher SSA (Fig. 3).

pH of the reactor run under $0.5 \text{ CODkg/m}^3/\text{d}$ OLR always showed a pH value greater than 6.3. But during the run with other three OLRs, at the beginning pH was below 6.0. OLR 1.0 and $2.5 \text{ CODkg/m}^3/\text{d}$ took about 15 days to increase the pH more than 6. But during the run under $3.5 \text{ CODkg/m}^3/\text{d}$ OLR it took about 40 days to achieve a pH of more than 6 (Fig. 4).

No special patterns were observed in removing biomass from the test reactor under any of four OLRs. Therefore the linear trend was analysed. Decreasing trends in SS content were observed under four OLRs tested, which was significant only during $0.5 \text{ CODkg/m}^3/\text{d}$ OLR at 0.05 probability level. When increasing the OLR, a high degree of fluctuations was observed in the SS content of effluent (Fig. 5). SS removal from the reactors showed a declining trend but significant during run with $0.5 \text{ CODkg/m}^3/\text{d}$ OLR. This behavior would be due to low biomass growth with low OLR, resulting in accumulation of biomass and also the reactor was having enough SSA to accommodate the biomass growth during the period reactor was monitored. Removal of SS during higher OLRs was more or less continuous.

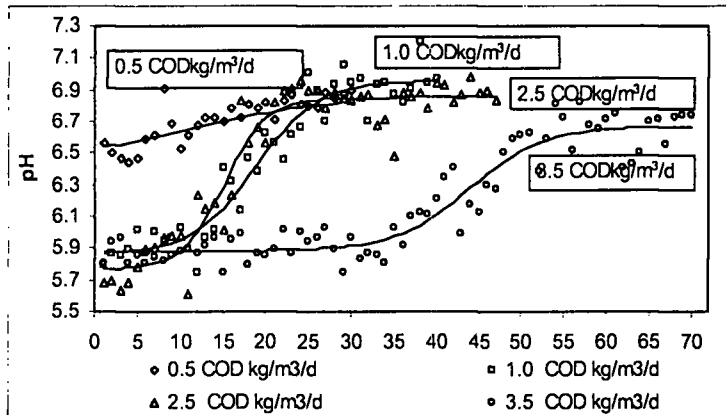


Fig. 4. pH of reactor with $200 \text{ m}^2/\text{m}^3$ SSA under different OLRs.

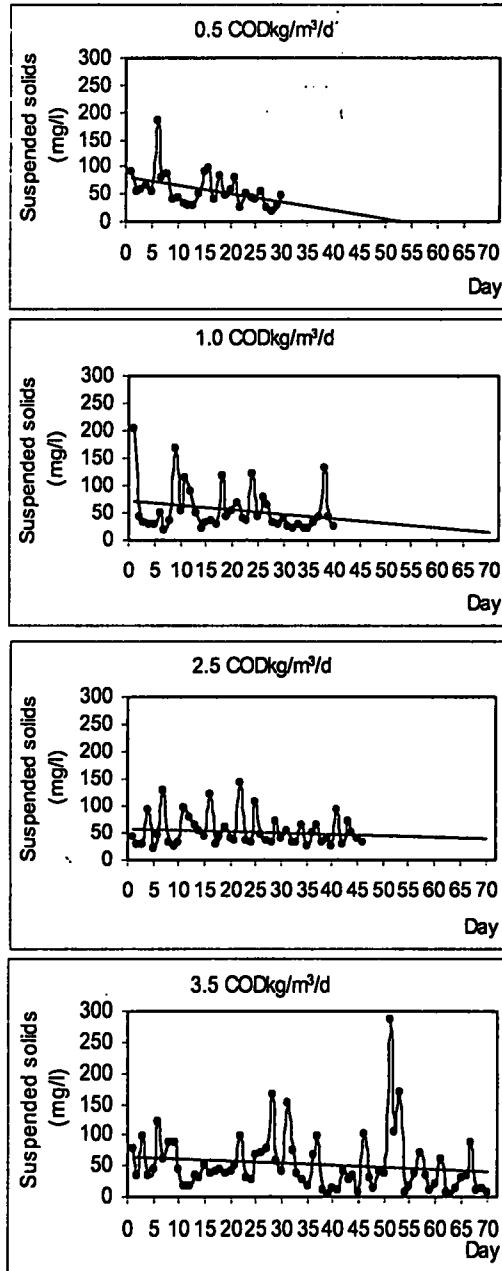


Fig. 5. SS of the effluent of reactor with 200 m²/m³ SSA under different OLR

Bio-brush medium on efficiency of CAD reactor

COD of the reactor with 200 m²/m³ SSA was about 100 mg/l and pH of reactor varies between 6.7 to 7.2. SS of the effluent was between 26 to 43 mg/l (except in day 38) after maturation of the reactor.

Conclusion

The best combination of SSA and OLR for anaerobic filter type CAD reactor is 200 m²/m³ SSA and 1.0 CODkg/m³/d. Under this OLR, correction of pH could be avoided to achieve an efficient treatment. However, correction of pH of reactor is preferred during higher OLRs. Continuous removal of SS from the reactors helps prevention of clogging of reactor, specially during operating under higher OLRs.

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