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Effect of nitrogen and processing chemicals on the treatment efficiency of crepe rubber factory wastewater

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Abstract

Crepe rubber industry being a major water polluting industry in Sri Lanka, there is a necessity for developing suitable treatment technologies for management of the problem. Biological treatment methods are accepted in treatment of crepe rubber factory effluent. To ensure a safe and stable operation of a biological treatment system, monitoring of environmental factors is important. Effect of nitrogen content and processing chemicals (as toxic substances) of factory effluent was estimated as environmental factors. Many researches have revealed that a COD: N of 100: (10-1) is beneficial for anaerobic treatment. Varying amounts of nitrogen in crepe rubber factory effluent and the presence of processing chemicals, were found to affect the efficiency of treatment.

Key words: biological wastewater treatment, crepe rubber, nitrogen, processing chemicals, rubber factory effluent

Introduction

The Central Environmental Authority (CEA) of Sri Lanka has identified the natural rubber processing industry as one of the most significant water polluting industries in the island. Anaerobic treatment of waste is a simple and cost effective method of treatment, which can contribute significantly to the improvement of environmental standards. As anaerobic filters are highly resistant to organic and hydraulic overloads, they are of advantage in treating rubber factory wastewater. Recent developments in digester design and advances in understanding of microbiology of the process, have led to significant improvements in the potential use of anaerobic method for industrial wastewater treatment.

In anaerobic biological wastewater treatment, maintaining an adequate amount of active biomass is the key to a safe and stable operation (Young, 1991). Of the known methods for retaining biomass for obtaining high concentrations of active biomass, immobilization of inert support media have been found to be quite effective (Aivasidis & Wandrey, 1988; Kennedy & Droste, 1991).

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For achieving a fast growth of the starter culture, maintenance of optimum environmental parameters in the reactor is necessary. The nutrient content of the feed must be balanced (Weiland & Rozzi, 1991). A COD: N ratio in the range 100: (10-1) have been reported to be beneficial (Kennedy & van den Berg, 1985; Iza *et al.*, 1991). In case of unbalanced nutrient levels, the addition of nutrients is necessary during start-up operation for effective functioning of anaerobic treatment systems (Weiland & Rozzi, 1991).

Crepe rubber factory effluent contain proteins, sugars, organic acids, nitrogen, phosphorus and potassium as major constituents and also remains of chemicals used during processing rubber *i.e.* sodium sulphite, sodium bisulphite, tolyl mercaptan and formic acid. With the exception of formic acid, other chemicals in crepe rubber effluents could affect the efficiency of biological reactors. The objective of this investigation was to study the effect of nitrogen and processing chemicals on the efficiency of biological reactors.

Materials and Methods

Reactor preparation

Laboratory scale 54*l* glass tanks were used as the test reactors. Bio-brushes, a coir based medium was set in the test reactors as the stationary medium. With the results obtained from preliminary studies, 200 m^2/m^3 specific surface area (SSA) of medium, 1.0 kg $COD/m^3/d$ organic loading rate (OLR) and 2.66 days of retention time was set as those running condition were observed as the most beneficial for crepe rubber factory effluent treatment.

Anaerobic sludge collected from the crepe rubber factory wastewater treatment system at Rayigam estate, Ingiriya was used as the seed sludge. 5*l* of mixed liquor of seed sludge (approximate suspended solids content is 5000 mg/l) was introduced into each reactor. Reactors were kept one day, without disturbing. Diluted rubber factory effluent with an approximate chemical oxygen demand (COD) of 150 mg/l was introduced as the feed for a period of 2 weeks. COD of the feed was increased gradually in 50 mg/l up to reach 750 mg/l weekly.

Nitrogen content of effluent

A test run of the reactor was with crepe rubber factory wastewater in which the COD: N ratio was adjusted to 100: (10 -1) as this ratio seems to be beneficial for a good anaerobic treatment (Kennedy & van den Berg, 1985; Iza *et al.*, 1991). Nitrogen content was adjusted using urea as the nitrogen source. At the same time another test reactor with same characteristics was run with normal rubber serum for comparison. Daily COD values of treated effluent were measured until both reactors reached a steady state (50 days) and COD removal efficiency was calculated subsequently and the data were subjected to statistical analysis to see whether there is any significant differences between treatments.

Chemicals, used during processing

Recommended levels of chemicals, used during crepe rubber production, were introduced into field latex and subjected to coagulation (Gunetilleke, 1984). Test reactor was run using this serum. At the same time, another test reactor with same characteristics was run with serum, collected by coagulation of field latex, to which no recommended process chemicals were added. Daily COD values were measured until both reactors reached a steady state (50 days) and the calculated COD removal efficiency values were subjected to statistical analysis to see whether there is any significant differences between treatments.

Analytical assessments

Closed reflux colorimetric method (APHA, 5220D) was used to measure COD. Total nitrogen content was determined by using semi-micro Kjeldahl procedure.

Statistical analysis

Using a paired t-test, COD removal % (rem%) of reactors at different time segments were analysed statistically. Using GenStat statistical software, standard logistic curves were fitted for both cases using the equation depicted below.

$$Y = \alpha + \gamma / [1 + \exp(-\beta (X - \mu))]$$

From the parameter estimates β is a slope parameter, μ is the point of inflexion for the explanatory variable. $\alpha + \gamma$ is the upper asymptote and α is the lower asymptote.

Results

Effect of nitrogen content of rubber serum on treatment

Two equal laboratory scale test reactors set with 200 m^2/m^3 SSA of Bio-brush media was run under 1.0 CODkg/m^3/d OLR using normal effluent (Reactor-1) and effluent of which nitrogen content was corrected to give the amount described by Kennedy & van den Berg, 1985 and Iza *et al.*, 1991 (Reactor-2). Daily COD values of the effluent were measured in each reactor and daily COD rem% were evaluated. Results were analysed statistically and depicted in the figure 1.

Parameter estimates	Reactor-1	Reactor-2
β	0.1793 (± 0.0324)	0.1197(± 0.0255)
μ	29.16 (± 1.03)	17.43 (± 2.07)
γ	20.22 (± 1.55)	20.60 (± 2.93)
α	66.655 (± 0.732)	72.53 (± 2.35)

(±standard error)

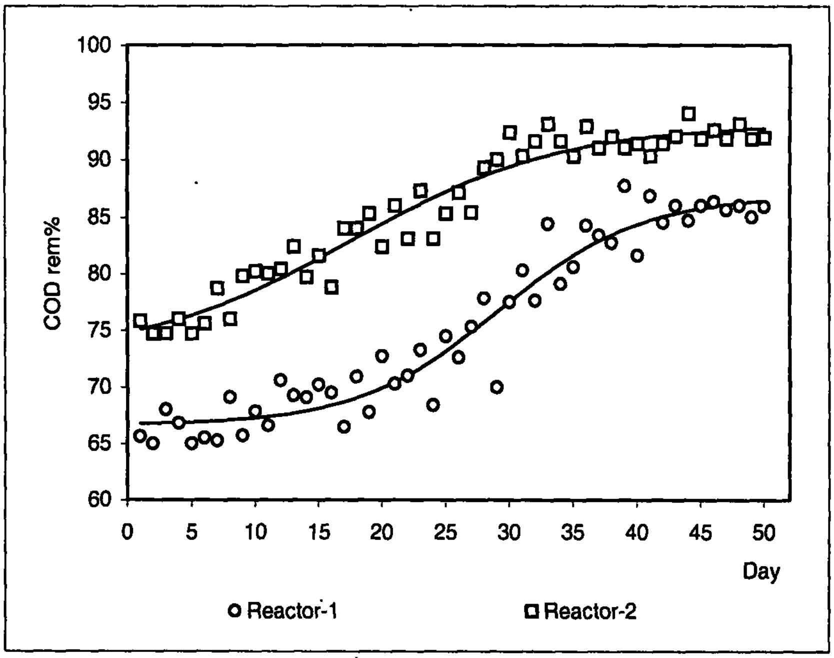

Fig. 1. COD rem% of the reactors run with normal effluent (Reactor-1) and nitrogen content corrected effluent (Reactor-2)

COD rem% of the two reactors was significantly different from each other at 0.001 probability level. During the 50 days of test period the COD rem% of the Reactor-1 was lower than that of the Reactor-2. Reactor-1 took about 10 days to show a noticeable increase in COD rem% at the beginning of the test. But COD rem% of the Reactor-2 showed a gradual increase from the start (Fig. 1). The mean COD rem% of the Reactor-1 was 75.3 with a minimum and maximum COD rem%, 65.0 and 87.7 respectively. The mean, minimum and maximum COD rem% of the reactor-2 were 85.8, 74.7 and 94.0 respectively.

Effect of chemicals used during crepe rubber processing on treatment

Two equal laboratory scale test reactors set with 200 m^2/m^3 SSA of Bio-brush media were run under 1.0 CODkg/m^3/d OLR using chemical free effluent (Reactor-1) and effluent with processing chemicals (Reactor-2). Daily COD values of the effluent were measured in each reactor and daily COD rem% were evaluated. Results were analysed statistically and depicted in the figure 2.

Parameter estimates	Reactor-1	Reactor-2
β	0.3187 (±0.0235)	0.1234 (±0.0221)
μ	28.85 (±0.261)	28.90 (±1.29)
γ	19.944 (±0.402)	25.81 (±2.62)
α	72.25 (±0.231)	64.92 (±1.14)

(± standard error)

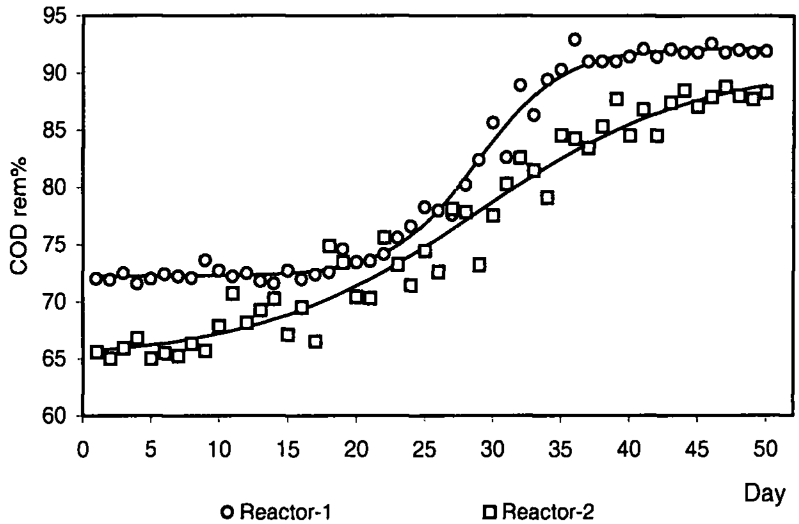

Fig. 2. COD rem% of the reactors run with chemical free effluent (Reactor-1) and effluent with processing chemicals (Reactor-2)

COD rem% of the two reactors was significantly different from each other at 0.001 probability level. During the 50 days of run the COD rem% of the Reactor-1 was higher than the COD rem% of Reactor-2. From day 1 to 25 the difference of COD rem% of both reactors gradually decreased and from day 25 to 35 the difference gradually increased. The COD rem% of the Reactor-1 seems to be approaching a steady state after day 40. But at the end of the run the COD rem% of Reactor-2 did not come to a steady state (Fig. 2). Moreover the COD rem% of the Reactor-2 showed a high degree of fluctuations than the Reactor-1. Mean COD rem% of Reactor-1 and Reactor-2 was 80.89 and 76.23 respectively. Reactor-2, which was run with effluent with chemicals, showed a maximum COD rem% of 88.80 while the maximum COD rem% of the Reactor-1 was 92.90.

Discussion

For achieving a fast growth of the biomass, maintenance of optimum environmental parameters in the reactor is necessary. The nutrient content must be balanced (Weiland & Rozzi, 1991). A COD: N ratio in the range 100: (10-1) seems to be beneficial (Kennedy & van den Berg, 1985; Iza *et al.*, 1991). In the case of nutrients unbalanced, for an effective anaerobic treatment of wastewater, the addition of nutrients is necessary during start-up operation (Weiland & Rozzi, 1991).

Often the COD/N ratio or COD/N/P ratio is used to describe the nutrient requirement in reactors. Only the nitrogen requirement is considered, as the phosphorous requirement is of a magnitude that has only minor economic implications (Henze & Harremoes, 1983). The minimum theoretical COD/N - ratio is 350/7. van den Berg & Lentz (1977) in their studies found that a value around 400/7 must be regarded reasonable for high loaded anaerobic processes (0.8 - 1.2 kg COD/kg vss.d). For low loaded processes (0.5 kg COD/kg.vss.d) the COD/N ratio is seen to increase dramatically to values of 1000/7 or more (Matensson & Frostell, 1982; van den Berg & Lentz, 1980).

Nitrogen content of the crepe rubber factory effluent directly affects the COD removal efficiency of reactors (Fig. 1). COD rem% of the reactor run with nitrogen content adjusted to a C : N ratio of 100 : (10-1) showed a considerably high COD rem% than the reactor run with normal serum. It also showed a fast start-up (Fig. 1).

Crepe rubber factory effluent contains about 15 mg/l of sulphides and 190 mg/l sulphites (Anon, 1992) and this could affect the efficiency of treatment system. Non-toxic sulphite and sulphate are converted to toxic sulphide under anaerobic conditions. The toxicity of sulphide is closely related to free hydrogen sulphide concentration. This means that low pH (<6.5) experienced in anaerobic reactors increases toxicity, whereas the presence of iron reduces toxicity due to precipitation of ferrous sulphide (Henze & Harremoes, 1983). For general operation, sulphate-sulfur concentrations in the influent below 0.3 - 0.6 kg/m^3 should be regarded harmless, but as mentioned previously, pH and precipitation can change the picture radically (Henze & Harremoes, 1983). During the run with chemical free serum, the reactor showed a significantly high COD removal efficiency than the run with factory effluent with chemicals (Fig. 2). Formic acid, which is used in coagulation of latex is harmless and could be digested biologically under anaerobic environment.

Conclusion

Nitrogen content of the crepe

rubber factory effluent and the presence of processing chemicals in effluent, directly affected the efficiency of the anaerobic reactor. The efficiency of a reactor designed for crepe rubber factory effluent can therefore be improved by adjusting the nitrogen content of effluent.

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