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Simultaneous Adsorption and Biodegradation of Reactive Dyes using Jatropha Deoiled Cakes

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Abstract*: *Endemic pollution problems due to discharge of wastewaters are affecting all the aspects of human life. The poor quality effluents coming from industries is destroying the fragile ecosystem, leading to various apprehensions amongst researchers and scientific communities. Treatment of wastewaters have become an urgent need of the society, which cannot be ignored. Incineration, absorption on solid matrices and biological treatment are some of the effluent treatment methods available. These methods, however, have their own disadvantages. This work explores the application of jatropha deoiled cakes on the concurrent adsorption and biological degradation of reactive dyes. Reactive blue, reactive yellow, reactive red were used for the experiments. The combined experiments were tested for effect of glucose concentrations as well as initial concentrations. Glucose concentrations of 1 g/l, 2 g/l and 3 g/l were taken. All the dyes were varied from 100 ppm to 600 ppm. It was observed that combined degradation yielded higher degradation compared to biological degradation alone. The degradation rate varied with the variation of glucose concentration and it also varied with the initial concentration.

Keywords: Biological Degradation, Jatropha Deoiled Cakes, Reactive Dyes, Simultaneous Adsorption

I. INTRODUCTION

Water is the primary component of all essential social and economic procedures. Due to the growth of consumer society, dangerous chemicals are generated in vast amounts throughout the globe. The issues arising from the toxicological impacts of these organic compounds must be resolved for the benefit of society as a whole. The issue is definitely complicated, and it is essential that novel processes are needed to cope with this wide spectrum of problems. The scenario is alarming due to the absence or insufficiency of appropriate wastewater treatment techniques capable of decreasing toxic substances that currently pose a constant chemical threat. There are extensive treatment technologies for sewage, distillery and so on that contain biodegradable organics, but not so much for toxic effluents that contain xenobiotic compounds that are often non-biodegradable or only partly biodegradable.

When a gas or liquid solute accumulates on the surface of a solid or a liquid, forming a film can be referred as adsorption.

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Biological treatment processes are designed to remove the biodegradable content of the wastewaters. Biological treatment process uses different microorganisms (i.e., algae, fungi, and bacteria) to degrade organics. Biological processes are the most adaptable method for wastewater treatment. These are eco-friendly and also economically feasible. They possess the capability of degrading a range of compounds, including PAHs, explosives, chlorinated organics, etc. However, toxic chemicals treatments are not feasible as clean water seems to have appreciable concentration of these chemicals. Hence, it becomes necessary to develop effective technologies to remove these toxic compounds. This work proposes simultaneous adsorption and biological degradation of different dyes using Jatropha deoiled cake as an adsorbent.

II. MATERIALS AND METHODS

i) Compounds selected for Experiments

The following Reactive dyes (Blue, Yellow and Red) were obtained from Merck India.

ii) Microorganism and its development

This study involves only mixed cultures for degradation of toxic chemicals. The mixed cultures were developed from wastewater samples collected from a local sewage treatment plant (STP) near Vallam, Thanjavur.

The mixed culture was maintained with a medium containing glucose as the source of carbon. The mixed culture was maintained at 4^{o}C. The sub culturing period was 7 days.

The cultures were acclimatized to all the chemicals for 2 to 4 weeks before experimentation. Figure 1 shows the mixed culture used in the experiments.

Figure 1. Mixed cultures used

The media concentration were kept same throughout the study whereas the concentration of glucose and the nutrients were varied according to the requirements.

iii) Adsorbents and their preparation

Jatropha Deoiled Cakes (JDC) were collected from Bannari Amman sugar mills, Sathyamangalam, Erode.

They were dried overnight at 105oC in a hot air oven, followed by crushing and sieved with a 125 μm mesh. The powdered samples were dried using a desiccator and stored in airtight containers for subsequent analysis.

The dried adsorbents were impregnated with H_3PO_4 in the ratio of 1:2. The activation method involves use of 100 g of adsorbents with 120 ml of H_3PO_4 mixed and kept overnight in room temperature. It was then kept in a muffle furnace in the presence of nitrogen atmosphere at 500°C for 2 hours. The samples so generated were washed with distilled water until the pH becomes neutral. Then the powder obtained was dried and sieved (at 125 microns) for the adsorption process.

iv) Preparation of Stock Solution

The stock solutions of the reactive dyes (1000 ppm) were prepared by dissolving one gram of dye in a litre of distilled water.

III. EXPERIMENTAL PROCEDURE

Six different initial concentrations of dye were used in the experiments (100 to 600 ppm). Three different glucose concentrations (1 g/l, 2 g/l and 3 g/l) and four different temperatures (25, 30, 35 and 40^{0}C) were used for the biological experiments. The experiments were also conducted for cultures without glucose. The experiments were run for a week. All measurements were repeated to minimise the errors. The inocula concentration was fixed at 15%.

The test experiment was constituted of media with biomass and adsorbents. Optimized adsorbent dosage would be added to test solution containing media, and biomass. A ratio of 5:1 was observed for adsorbent: chemical for dyes. For E.g., 100 ppm initial concentration of dye would have the adsorbent 50 mg in 100 mL solution. And for 600 ppm dye solution, the adsorbent added would be 300 mg.

IV. ANALYSIS

A. pH

pH of all the reactors were analyzed using Water Analyzer 371.

B. Biomass concentration determination

The biomass concentration was measured by the optical density values. The optical density was determined from the reactors without centrifuging was recorded and multiplied with its dilution factor to arrive the Biomass concentration. The analysis was done at 600 nm using a Double Beam Spectrophotometer (Make: Systronics, Model: 2202)

C. Spectrophotometric measurement of Dyes

The three reactive dyes (red, blue and yellow) were taken at different concentration and their optical densities obtained by UV-spectrophotometer (Make: Labinda, Model: 3100) were estimated at respective wavelengths (Table 1). A calibration curve was obtained between optical density and concentration for each of the dye, which were found to be linearly dependent. A calibration equation was generated from calibration curve for all the dyes.

Table 1 Measuring wavelength for the dyes

S.No	Dyes	Wavelength (nm)	R^2
1	Reactive Red	540	0.9965
2	Reactive Blue	614	0.9776
3	Reactive Yellow	418	0.9994

D. Chemical Oxygen Demand

Chemical oxygen demand was measured using Hach Colorimeter (DR 890) and HACH COD digester. The COD solution (HR grade – 0-1500 ppm) was prepared by mixing 0.25 ml of COD solution A and 2.8 ml of COD solution B. Before keeping for digestion in the COD reactor, 2 ml of centrifuged sample was added. The digestion was done at 150^{0}C for two hours using COD vials. The COD values were recorded.

V. RESULTS AND DISCUSSIONS

i) Effect of glucose concentration

Simultaneous removal of dyes for integrated treatment at different glucose concentrations (0 g/l, 1 g/l 2 g/l and 3 g/l) were tested. It was compared with biodegradation alone. COD removal data for the dyes (RB, RY, and RR) are presented in Figures 2, 3 and 4 for biodegradation.

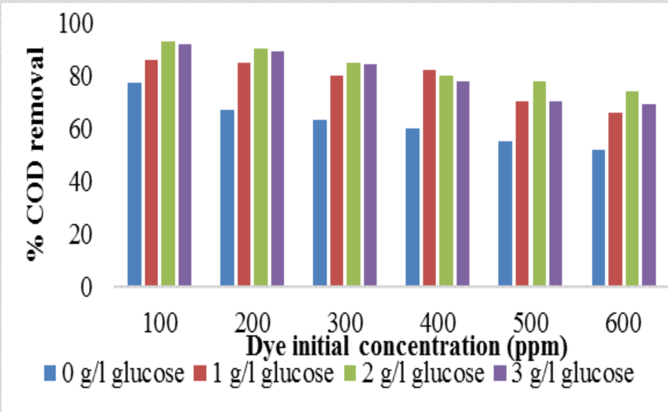

Figure 2. COD removal of Reactive Blue dye

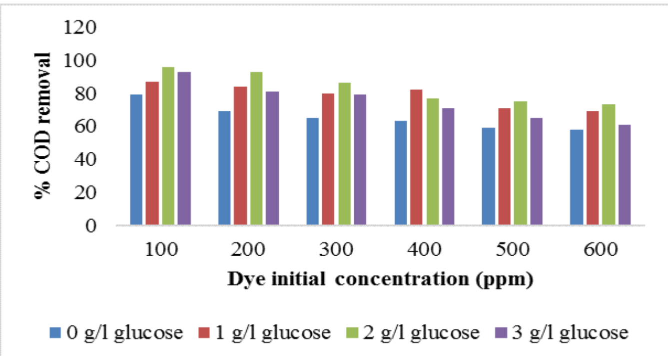

Figure 3. % COD removal of Reactive Red

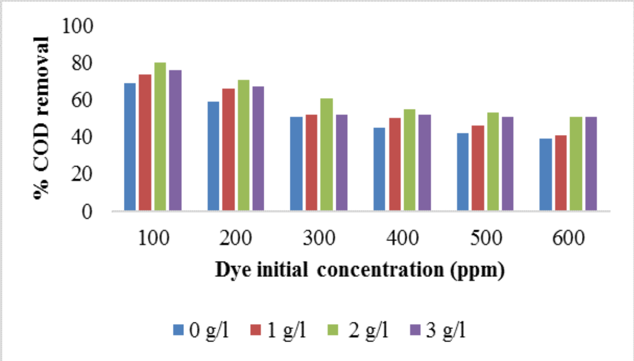

Figure 4. % COD removal of Reactive yellow

The combined treatment using adsorption and biological treatment was conducted in simultaneous mode. Both adsorption and biodegradation were tested simultaneously. COD removal data for the dyes (RB, RY, and RR) are presented in Figures 5, 6 and 7 for biodegradation in simultaneous mode.

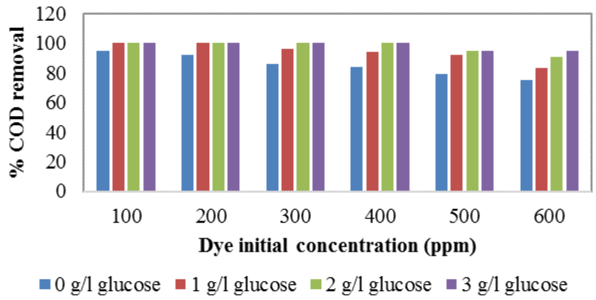

Figure 5. Biodegradation of Reactive Blue in simultaneous mode

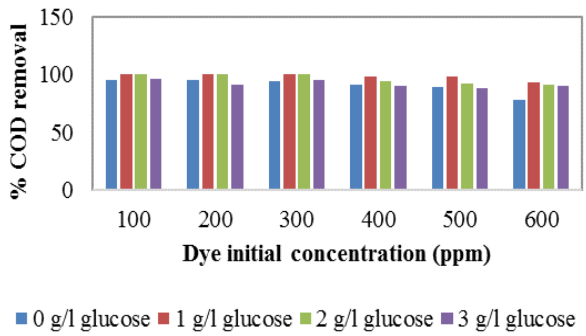

Figure 6. Biodegradation of Reactive Red in simultaneous mode

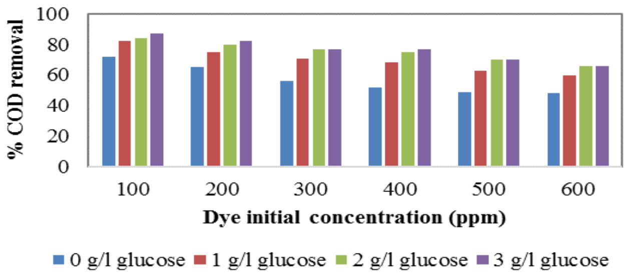

Figure 7. Biodegradation of Reactive Yellow in simultaneous mode

Another parameter, % point change (Pp) was used to compare integrated treatment with biodegradation alone. It shows the increase in degradation with respect to biological treatment (Fig. 8, 9 and 10). It is the ratio of difference between integrated reduction and biological reduction divided by biological reduction. Higher is the Pp value, higher is the efficiency of the integrated process.

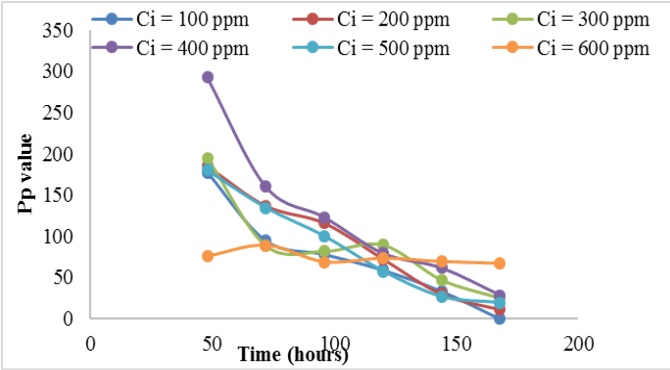

Figure 8. Percentage point change in Reactive Blue at different initial concentrations

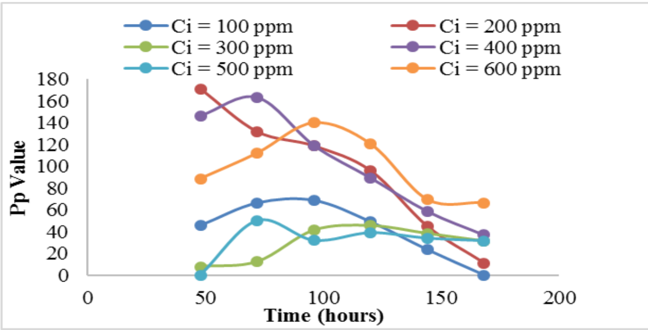

Figure 9. Percentage point change in Reactive Red at different initial concentrations

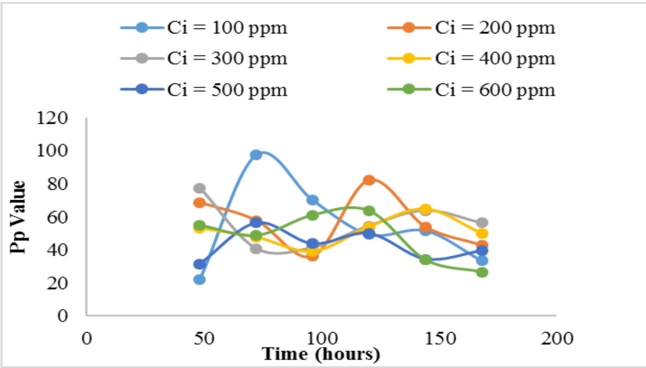

Figure 10. Percentage point change in Reactive Yellow at different initial concentrations

It was found that COD removal increased gradually from no glucose to 1 g/l glucose concentration for reactive blue. It was 75% for no glucose, which increased to 83% for 1 g/l. It further increased to 91% for 2 g/l and 95% for 3 g/l glucose. Reactive Red, on the other hand presented mixed variations, as COD removal showed 78% at 0 g/l to 93% at 1 g/l. It could be that substrate inhibition is being demonstrated here, but was less profound than that observed for biodegradation alone.

ii. Effect of initial concentration

Experiments were conducted on the influence of initial concentration in simultaneous adsorption and biodegradation process. As mentioned earlier, both biodegradation and adsorption was conducted in the same reactor. It can be noted that simultaneous degradation has been very effective in degrading the dyes. 100 ppm RB solution was completely degraded in three days and higher concentrations (600 ppm) was degraded by the end of seven days. The degradation rate was much faster than that of biodegradation alone. The Pp value was observed to increase with increase in concentration. At 200 ppm, Pp value was 19%, which increased to 48% for 300 ppm of RR solution. At high concentration, biological degradation is not so effective since microbes are more susceptible to toxicity effects. Though there is an increased substrate concentration for them, the dyes are not biogenic substrates and hence have the potential to interfere with the microbial metabolism (Goel et al., 2009). Even though, there is an increase in Pp value, many non-biodegradable components may still be present, which would be difficult to degrade. Simultaneous mode promotes more biodegradability by adsorbing non-biodegradable compounds (Seo et al., 2001; Orozco et al., 2008). This is a favorable situation for biodegradation as microbes could grow faster by consuming biogenic substrates and thus increase the rate of biodegradation of dyes and other chemicals. These results are important as the presence of bio-refractory materials hindered the biological degradation rate. However, biological treatment processes are most versatile and economical, the bio-refractory materials inhibit the biological activity of microorganisms (Goel et al., 2010). Therefore, a combination of biological and physico-chemical process is more effective.

The effects of initial concentrations are further compared using mineralization data. In case of RB, biodegradation alone could yield only 76% COD removal for 600 ppm solution, but a high COD removal of 100% was observed for simultaneous mode. Individual chemical degradation is much easier in most of the processes, but COD removal or mineralization is more complicated. The degradation of individual chemicals generate plenty of intermediates, and sometimes they are much more recalcitrant than parent chemicals (Goel et al., 2010). It can be noted that all the dyes showed marginal to significant increase in COD removal when conducted in simultaneous mode.

VI. CONCLUSION

• Simultaneous adsorption and biological degradation was conducted for all the chemicals and effect of glucose concentration and initial concentration was tested.

• It was observed that increase in glucose concentration increased the COD removal for all the chemicals, though, there were some exceptions. Reactive blue and reactive red both yielded 91% COD removal for 600 ppm dye solution.

• An innovative and novel process like simultaneous adsorption using deoiled cakes is more successful in degrading the toxic chemicals compared to conventional treatment methods.

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