Treatment of Dairy Industry Wastewater – A Novel Adsorbent Tamarind Kernel Powder

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Abstract— **The effectiveness of tamarind kernel powder, a cheap agro-based product, was evaluated to remove BOD and TDS present in a dairy industry wastewater. Experiments were carried out by adding tamarind kernel powder to the dairy industry wastewater at different dosages, different rapid mixing contact time and slow mixing contact time. Maximum removal of 88.8 % and 92.1 % respectively for BOD and TDS was obtained at an optimum dosage of 70 g/l, an optimum rapid mixing contact time of 10 min. and an optimum slow mixing contact time of 30 min. In order to investigate the consistency, experimental data obtained in this study were validated with the removal of other parameters in a dairy industry wastewater against the identified optimum process parameters value. The study was extended to fit the experimental data into isotherm model. The model result showed that the Freundlich isotherm model was fitted well with the experimental data of dairy industry wastewater. Based on experimental and model studies, tamarind kernel powder is effectively used as adsorbent for reducing the BOD and TDS present in the dairy industry wastewater.**

Keywords— **Dairy industry wastewater, BOD, TDS, Process parameters, Freundlich Model**

I. INTRODUCTION

The dairy industry is a major source of food processing wastewater. Dairy industry wastewater generally contains a high organic load, due to the presence of diluted milk/milk products, and contains significant quantities of cleaning and sanitizing compounds. The dairy industry in India is generated 6-10 litres of wastewater per litre of the milk processed. Wastewater management in the dairy industry is well documented, but wastewater production and disposal remain a problematic issue. The discharged wastewater is generally contaminated the surface water and groundwater, results increased water pollution [6].

There are several processes that can be adopted for the treatment of industry wastewater such as such as reduction followed by chemical precipitation, sedimentation, electrochemical processes [9,12], ion exchange, biological operations, bioremediation [7,8,10,17,18,22], biosorption [4,13,23], cementation, coagulation / flocculation [17], filtration and membrane processes, and solvent extraction.

In recent years, increasing awareness of water pollution and its far reaching effects has prompted concerted efforts towards pollution abatement. Earlier works revealed the suitability of variety of agro-based materials like moriga oleifera seed, corncob, groundnut husk, rice husk, tea leaves carbon, saw dust to treat the industrial wastewater [2,3,5]. The adsorbent prepared from biomaterial has large surface area and micro porous character nature have made them potential adsorbents for the removal of heavy metals from industrial waste water [11,14-16,19-21].

The present study aims to determine an effect of tamarind kernel powder for removing Biochemical oxygen demand (BOD) and total dissolved solids (TDS) present in the dairy industry wastewater at different dosages, different rapid mixing contact time and different slow mixing contact time. In order to investigate the consistency, experimental data obtained in this study were validated with the removal of other parameters in a dairy industry wastewater against the identified optimum process parameters value. Further, the study also extended to fit the experimental data into isotherm model.

II. MATERIALS AND METHODS

A. Adsorbent Preparation

Tamarind kernels were washed with tap water and then deionized water to remove particulate material from their surface. After that, they were dried in an oven at 100 ^oC for 24 hr. The dried materials were ground using pistol and mortar. The ground *tamarind kernel* was then sieved through 500 microns to get uniform geometrical size for use.

B. Collection and Analysis of Sample

For the present study, the wastewater samples were collected from dairy industry with the help of air tight sterilized bottles, took to the laboratory and then they were stored for analyzing various physico-chemical parameters. The characteristics of dairy industry wastewater is presented in Table 1.

TABLE 1
CHARACTERISTICS OF DAIRY INDUSTRY WASTEWATER

Sl.No.	Parameters	Values
1	pH	7.86
2	BOD	4680 mg/l
3	COD	5422 mg/l
4	TSS	4356 mg/l
5	TDS	5830 mg/l
6	Nitrogen	2368 mg/l
7	Phosphorous	523 mg/l

8	Chloride	530 mg/l
9	Sulphate	635 mg/l

The primary focus of the present study is to reduce the BOD and TDS concentrations in a dairy industry wastewater using *tamarind kernel* powder as adsorbent. In the present study, the Phipps and Bird jar test apparatus was used for evaluating and optimizing the coagulation process. This method consists of batch experiments involving rapid mixing at the rotational speed of 100 rpm, slow mixing at the rotational speed of 20 rpm for enhancing flocculation process and sedimentation for a period of 60 min. Dairy industry wastewater of 4th dilution (4 parts of well water and 1 part of Dairy industry wastewater) was filled in four glass beakers of 1 litre capacity and was kept in the Phipps and Bird jar test apparatus for agitation.

In the present investigation, the experiments were performed at different dosages (varying from 10 mg/l to 100 mg/l at an interval of 10 mg/l), different rapid mixing contact time (varying from 2 min. to 14 min. at an interval of 2 min.) and different slow mixing contact time (varying from 5 min. to 40 min. at an interval of 5 min.). Clear wastewater from each beaker after sedimentation was collected for analysing BOD and TDS as per standard procedure [1].

III. Results And Discussions

A. Effect of Tamarind kernel Powder Dosage

Fig. 1 shows effect of tamarind kernel powder as absorbent dosage on BOD and TDS variations in dairy industry wastewater with a rapid mixing contact time of 6 min. and a slow mixing contact time of 15 min.

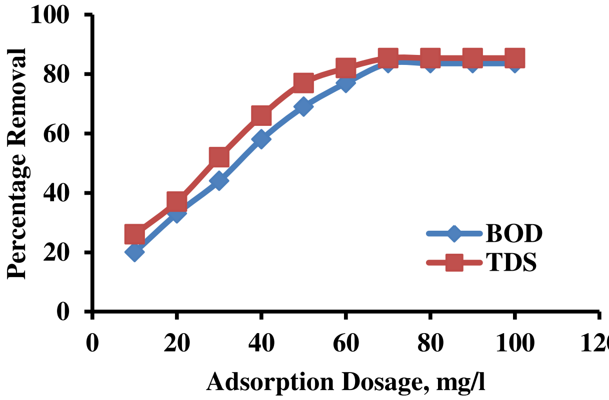

Fig. 1 Effect of Tamarind Kernel Powder Dosage

From Fig. 1, it may be observed that up to 70 g/l of tamarind kernel powder dosage, concentration of BOD and TDS in a dairy industry wastewater decrease, beyond which they reached steady state condition. The percentage reduction in concentration of BOD and TDS for a tamarind kernel powder dosage of 70 g/l was 83.6 % and 85.4 % respectively. Thus, an optimum dosage for which the maximum removal of BOD and TDS occurs is found to be 70 g/l (Fig. 1). Further, an optimum dosage, which is corresponding to the lowest residual BOD and TDS obtained for a dairy industry wastewater were 767.5 mg/l and 851.2 mg/l respectively.

B. Effect of Rapid Mixing Contact Time

Fig. 2 shows effect of rapid mixing contact time on BOD and TDS variation in dairy industry wastewater with an optimum dose of 70 g/l and a slow mixing contact time of 15 min.

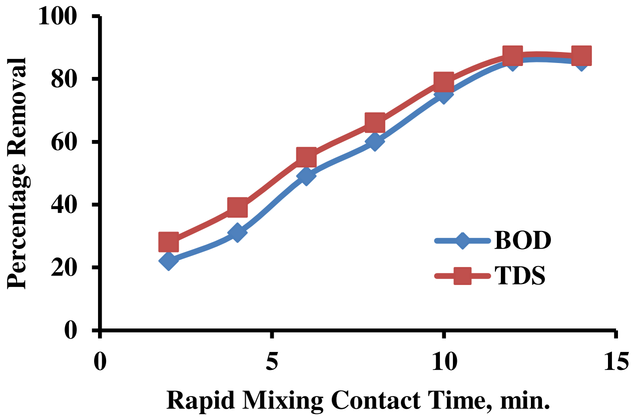

Fig. 2 Effect of Rapid Mixing Contact Time

From Fig. 2, it may be observed that up to 10 min. rapid mixing contact time, the concentration of BOD and TDS decrease, beyond which they reached steady state condition. The maximum percentage reduction in concentration of BOD and TDS was 85.5 % and 87.3 % respectively for a rapid mixing contact time of 10. Thus, an optimum rapid mixing contact time leading to maximum BOD and TDS removal is found to be 10 min. (Fig. 2). Further, an optimum rapid mixing contact time, which is corresponding to the lowest residual BOD and TDS obtained for a dairy industry wastewater were 678.6 mg/l and 740.4 mg/l respectively.

C. Effect of Slow Mixing Contact Time

Fig. 3 shows effect of slow mixing contact time on BOD and TDS variation in dairy industry wastewater respectively with an optimum dosage of 70 g/l and with an optimum rapid mixing contact time of 10 min.

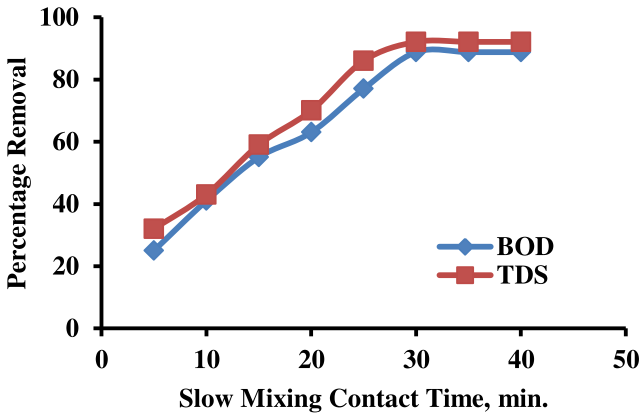

Fig. 3 Effect of Slow Mixing Contact Time

It can be observed from Fig. 3 that up to 30 min. slow mixing contact time, the concentration of BOD and TDS decrease and beyond which they reached steady state condition. The maximum percentage reduction in concentration of BOD and TDS for a slow mixing contact time of 30 min. was 88.8 % and 92.1 % respectively. Thus an optimum slow mixing contact time for which the maximum BOD and TDS removal occurs is found to be 30 min. (Fig. 3). Further, an optimum slow mixing contact time, which is corresponding to the lowest residual BOD and TDS obtained for a dairy industry wastewater were 524.2 mg/l and 460.57 mg/l respectively.

D. Validation Test

In order to verify the experiments conducted for the removal of BOD and TDS in dairy industry wastewater, a separate experiments were conducted for removing various other parameters present in the dairy industry wastewater at an optimum adsorbent dosage of 70 g/l, rapid mixing contact time of 10 min. and slow mixing contact time of 30 min. The results of the verification test are presented in the Fig. 4.

From the Fig. 4, it may be observed that the maximum removal of BOD, COD, TSS, TDS, nitrogen, phosphorous, chloride and sulphate are 88.1, 84.3, 88.6, 92.1, 86.7, 88.9, 84.4 and 86.8 % respectively. The above results are obtained for same an optimum adsorbent dosage of 70 g/l, rapid mixing contact time of 10 min. and slow mixing contact time of 30 min.

Thus, this study proved that the tamarind kernel powder is effectively used for removal of BOD and TDS present in dairy industry wastewater, in addition to other parameters also.

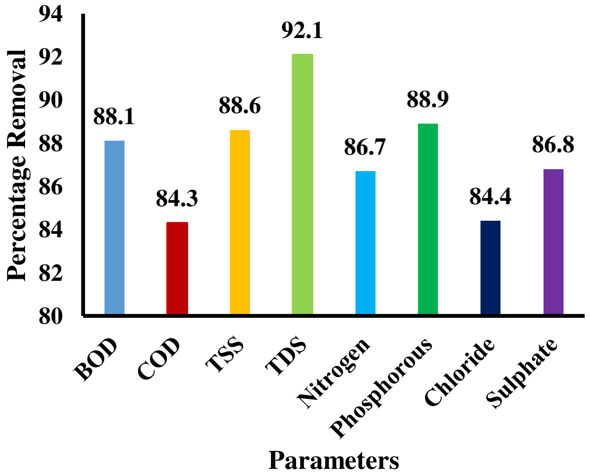

Fig. 4 Maximum Removal Percentage for Various Parameters in a Dairy Industry Wastewater at Optimum Adsorbent Dosage of 70 g/L, Rapid Mixing Contact Time of 10 min. and Slow Mixing Contact Time of 30 Min.

E. Equilibrium Study

Adsorption isotherms are mathematical models that describe the distribution of the adsorbate species among liquid and adsorbent, based on a set of assumptions that are mainly related to the heterogeneity/homogeneity of adsorbents, the type of coverage and possibility of interaction between the adsorbate species.

The Freundlich isotherm model is an empirical relationship describing the adsorption of solutes from a liquid to a solid surface and assumes that different sites with several adsorption energies are involved. In this study, the experimental data was fitted for the parameter BOD and TDS.

Freundlich adsorption isotherm is the relationship between the amount of BOD and TDS adsorbed per unit mass of adsorbent, q_e, and the concentration of the BOD and TDS at equilibrium, C_e.

$$q_e = K_f C_e^{1/n}$$

The logarithmic form of the equation becomes,

$$\log q_e = \log K_f + \frac{1}{n} \log C_e$$

Where, K_f and n are the Freundlich constants, the characteristics of the system. K_f and n are the indicators of the adsorption capacity and adsorption intensity, respectively. For this case, the plot of log C_e vs log q_e was employed to generate the intercept value of K_f and the slope of n.

The equilibrium study results of BOD and TDS are shown in Fig. 4 and Fig. 5 respectively.

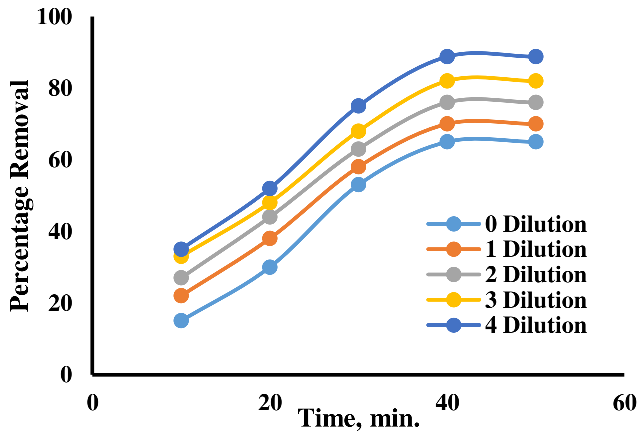

Fig. 4 Adsorption capacity against different concentration for the parameter BOD

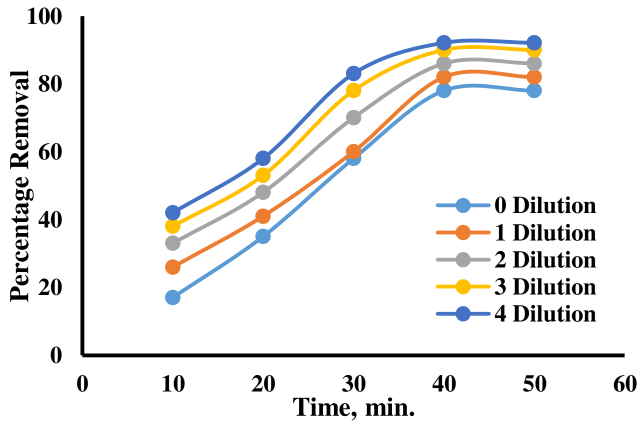

Fig. 5 Adsorption capacity against different concentration for the parameter TDS

The optimum adsorbent dosage of 70 g/l, rapid mixing contact time of 10 min. and slow mixing contact time of 30 min was used for conducting the equilibrium study against the different concentration (dilution ratio) at different contact time for the parameter BOD (Fig. 4) and

TDS (Fig. 5) respectively. From the Figs. 4 and 5, it may be observed that the maximum removal of BOD and TDS was observed at dilution ratio of 4.

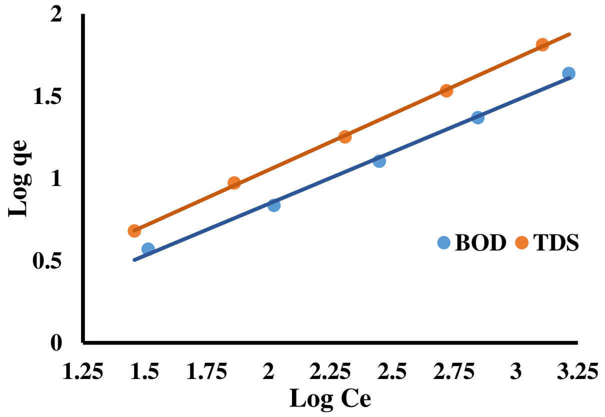

Fig. 6 Freundlich Adsorption Isotherm for the parameter BOD and TDS

Freundlich adsorption isotherm for the parameter BOD and TDS is represented in Fig. 6. It can be seen from Fig. 6 that the equilibrium data fits well with the Freundlich equation for both BOD and TDS parameters. The equation fitted with the experimental data for BOD and TDS are presented below.

y = 0.6301x - 0.4148 (BOD)
y = 0.6797x - 0.3075 (TDS)

The coefficient of determination (R^2) for BOD and TDS are 0.996 and 0.999 respectively. The constant K_f for BOD and TDS are 2.60 and 2.03 respectively and corresponding n values are 1.58 and 1.47 respectively for the parameter BOD and TDS.

The maximum removal from the experimental investigation for BOD is 3.71 mg/g and from the model for the same parameter is 3.65 mg/g. Similarly, the maximum removal from the experimental investigation for TDS is 4.79 mg/g and from the model for the same parameter is 4.76 mg/g.

Based on the results obtained from the isotherm model, Freundlich isotherm model could be reproduced the experimental results for the removal of BOD and TDS in a diary industry wastewater using tamarind kernel powder.

IV. Conclusions

In the present study, experiments was conducted to find out the suitability of tamarind kernel powder as adsorbent for removing BOD and TDS present in a dairy industry wastewater. The ability of tamarind kernel powder for removing BOD and TDS with different dosages, different rapid mixing contact time and different slow mixing contact time were monitored. The results showed that maximum percentage obtained at an optimum dosage of 70 g/l, an optimum rapid mixing contact time of 10 min. and an optimum slow mixing contact time of 30 min. The experimental investigation was verified and the results of the verification tests also showed that the maximum removal of other parameters in a dairy industry wastewater occurred at the same optimum dosage of 70 g/l, an optimum rapid mixing contact time of 10 min. and an optimum slow mixing contact time of 30 min. From the model studies, it could be observed that Freundlich isotherm fits well with the experimental data of BOD and TDS. Thus, from the experimental and model studies it can be concluded that the tamarind kernel powder is more beneficial in treating a dairy industry wastewater.

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