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Role of *Lemna minor* Lin. in Treating the Textile Industry Wastewater

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Abstract**—**Textile industry processes are among the most environmentally unfriendly industrial processes; because, they produce color wastewater that is heavily polluted the environment. Therefore, textile industry wastewater has to be treated before being discharged into the environment. In this study, experiments were conducted for different process parameters like nutrient dosage and dilution ratio against the pH and contact time to remove COD and color in a textile industrial wastewater using aquatic macrophytes *Lemna minor* L. The experimental results showed that the maximum percentage reduction of COD and color in a textile industry wastewater by *Lemna minor* L. was obtained at an optimum nutrient dosage of 50g, dilution ratio of 8, pH of 8 and contact time of 4 days. Similarly, the results of validation experiments showed that the experiments were able to reproduce the obtained optimum process parameters. The maximum removal percentage of color in an aqueous solution (86.35%) is higher than the removal of color in a textile industry wastewater (82.85). Further, the first order kinetic model was fitted well with the experimental data of this present study. Finally, this study concluded that *Lemna minor* L. may be used for removing all types of parameters in any type of textile industry wastewater.

Keywords**—**Aquatic Macrophyte, Process Parameters, Textile Industry Wastewater.

I. Introduction

TEXTILE industries consume a large volume of water and chemicals for making various textile goods. As a result, large volume of wastewater discharged on land with or without treatments. The quantities and characteristics of wastewater discharged on land varied from mill to mill, which depends on water consumption and production of average daily products from the industry [14].

Many approaches have been taken to reduce water consumption by recycling the wastewater comes from the textile industries. The raw materials, particularly dyes used in textile industry determine the volume of water required for production as well as wastewater generation [6]. The wastewater generated from the various processing units like desizing, scouring, bleaching, mercerizing, dyeing and printing units [2], [11], [12], [19].

The main parameters identified in the textile industry are color, pH, electrical conductivity (EC), chloride, sulphate, total dissolved solids (TDS), biochemical oxygen demand (BOD) and chemical oxygen demand (COD) and other solution substances [18], [19]. Among all parameters, the colored wastewater from a textile industry wastewater has heavily polluted the environment [22], [23], [26].

The wastewater from the any type of industries is passing through soil stratum linearly, leads to contaminate the nearby surface water and vertically, leads to contaminate the groundwater [24]. It is not only contaminating the water environment, but also contaminates the soil environment [21]. The important point is to be noted that all parameter values are exceeding the discharge standard limit. Therefore, it is necessary; wastewater from textile industry has to be treated before being discharged to the environment [16], [20].

Various methods, including coagulation [20], chemical oxidation, precipitation, filtration, membrane separation, electrochemical treatment [11] filtration, flotation, hydrogen peroxide catalysis, and reverse osmosis [3], ozonation [10] and biological methods [25] can be employed to remove various pollutants from textile industry wastewater [5]. However the treatment costs are high and most of them are difficult to use under field conditions, hence, there is an urgent need to study natural, simple, and cost-effective techniques for controlling pollution from industry wastewater and treating such wastewater using one of the cost effective method is phytoremediation [7], [8]. Phytoremediation is a method, in which, plants are used for accumulating various contaminants from water, wastewater, soil and air [4], [14], [17].

In recent years, considerable attention has been focused on absorption process using aquatic plants because, this method is having more advantages than conventional treatment methods include: low cost; high efficiency; minimization of chemical and biological sludge [15]. The application of phytoremediation technology by duckweed in wastewater treatment and management is quite interesting and revealing. *Lemna minor* L. known as common duckweed is a small, free floating aquatic plant fast growing, adapt easily to various aquatic conditions and play an important role in the extraction and accumulation of pollutants from water and wastewater [9], [13].

This study mainly focused to remove COD and color in a textile industrial wastewater using constructed wetland, aquatic macrophytes *Lemna minor* L. and different process parameters. Further, the experiment results in removal of COD and color concentration in a textile industrial wastewater are verified for their reproducibility. The reproducibility was checked by conducting a separate experiment for removing the same COD and color from an aqueous solution. Finally, kinetic model was developed to check the kinetics of experimental investigation of this present study.

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II. Materials And Methods

A. Collection of Lemna minor L.

Lemna minor L. was collected from the local pond, which had no connection with any textile wastewater discharge points. The collected *Lemna minor* L. was washed with deionized water and weighed. Further, the *Lemna minor* L. was initially subject to stabilization in small plastic tanks containing well water and the same were preserved for 10 days period. In addition, the plastic tanks were filled with gravel and wetland soil (collected from the local pond) up to five inches in height and maintained at normal temperature.

B. Collection of Textile Industry Wastewater

For the present study, textile industry wastewater was collected from the final clarifier of textile industry wastewater treatment plant of Chennai city, Tamil Nadu, India with the help of airtight sterilized bottles. Then, took wastewater samples to the Environmental Engineering Laboratory and then they were stored in the refrigerator at a temperature of 278K for analyzing chemical oxygen demand (COD) and color in later stages. In order to reduce the various parameters in a textile industry wastewater, wetlands was constructed (plastic tanks) by using *Lemna minor* L. and conducted the removal study with various nutrient dosages, dilution ratio and contact time.

C. Absorption Experiments

For the experiments, *Lemna minor* L., which maintained in the plastic tanks were collected, cleaned and introduced in the experimental tanks (constructed wetland). The experimental tanks also a plastic tank as similar to the plastic tank for preserving the *Lemna minor* L. Approximately, 100g of *Lemna minor* L. was used in each experimental tank for this study. These experimental tanks were filled with textile industry wastewater of 1000ml. Triplicate of each experimental setup was maintained.

In order to reduce COD and color in a textile industry wastewater, the experimental setup (constructed wetland) was examined for a period of 7 days with 1 day intervals using aquatic macrophytes *Lemna minor* L. The absorption study was conducted with various nutrient dosages (10, 20, 30, 40, 50, 60 and 70g) and dilution ratio (2, 4, 6, 8, 10, 12 and 14).

The nutrient used in this study was activated sludge, which was collected from Koyambedu Wastewater Treatment Plant. The dilution ratio was used such that 1 part of wastewater with various numbers of parts of well water, thus, the ratio of 2, 4, 6, 8, 10, 12 and 14 represents the parts of well water mixed with raw wastewater. The pH was adjusted by using 0.1 M of NaOH and 0.1 M of HCl.

The concentration of COD and color in a textile industrial wastewater before and after treatment with *Lemna minor* L. was determined as per the standard procedure stipulated by APPA [1]. The removal percentage of COD and color by *Lemna minor* L. was calculated by using (1):

$$\text{Percentage Removal} = \frac{(C_1 - C_2)}{C_1} \text{X } 100 \qquad (1)$$

in which C_1 is the concentration of COD and color before treatment with *Lemna minor* L. and C_2 is the concentration of COD and color after treatment with *Lemna minor* L. The concentration of raw wastewater from textile industry wastewater for COD and color is given in Table I.

TABLE I
The Concentration of Textile Industry Wastewater

Sl.No.	Parameters	Concentration
1	COD, mg/l	3458
2	Color (Acid Orange 10), mg/l	45

III. Results And Discussions

The different process parameters like nutrient dosage and dilution ratio were selected for conducting the constructed wetland absorption study using *Lemna minor* L. to reduce the various parameters like COD and color in a textile industry wastewater.

A. Effect of Nutrient Dosage

Experimental investigations were conducted by changing the nutrient dosage from 10g to 70g with an increment of 10g using *Lemna minor* L. and for the different contact time from 1 day to 7 days with an increment of 1 day. Fig. 1 indicates the percentage reduction of COD and color in a textile industry wastewater using *Lemna minor* L. against nutrient dosage (since, day 4 is the optimum contact time found from the study, the results obtained on the day 4 was presented and the results obtained from the day 1, 2, 3, 5, 6 and 7 were not presented in this study) with a contact time of 4 days, dilution ratio of 6 and pH of 8.

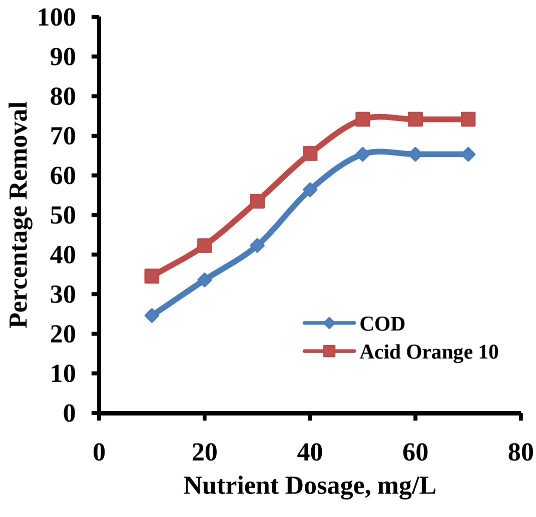

Fig. 1 The Percentage Reduction of COD and Color in a Textile Industry Wastewater using *Lemna minor* L. against Nutrient Dosage

The results revealed that the percentage removal of COD and color is low by *Lemna minor* L. at the starting time of the experiment and then increases with increasing nutrient dosage. This is because; the supplied nutrient could not be effectively utilized by *Lemna minor* L. for removing COD and color. Thereafter, as nutrient dosage increases, *Lemna minor* L. used nutrients effectively, results more removal of selected parameters by *Lemna minor* L. Up to nutrient dosage 50 g, the removal of COD and color in a textile industry wastewater increased steadily by *Lemna minor* L. and for the nutrient dosage of 60g and 70g, the percentage removal results showed the resembles of the results obtained nutrient dosage 50g. Hence, the optimum nutrient dosage found in this study for the maximum removal of COD and color in a textile industry wastewater by *Lemna minor* L. is 50g.

The removal percentage of COD and color was not significant even the nutrient dosages were higher; it is more likely that a significant portion of the available active sites remains undiscovered, leading to lower specific uptake for the nutrient dosage of 60g and 70g. The maximum removal percentage for COD and color in a textile industry wastewater by *Lemna minor* L. against nutrient dosage found in this study is 65.32 and 74.14 % respectively (Fig. 1).

B. Effect of Dilution Ratio

Experimental investigations were conducted by changing the dilution ratio from 2 to 14 (wastewater 1 : well water 2) with an increment of 2 using *Lemna minor* L. and for the different contact time from 1 day to 7 days with an increment of 1 day. Fig. 2 indicates the percentage reduction of COD and color in a textile industry wastewater using *Lemna minor* L. against dilution ratio with a contact time of 4 days (as similar to effect of nutrient dosage), the optimum nutrient dosage of 50g and pH of 8.

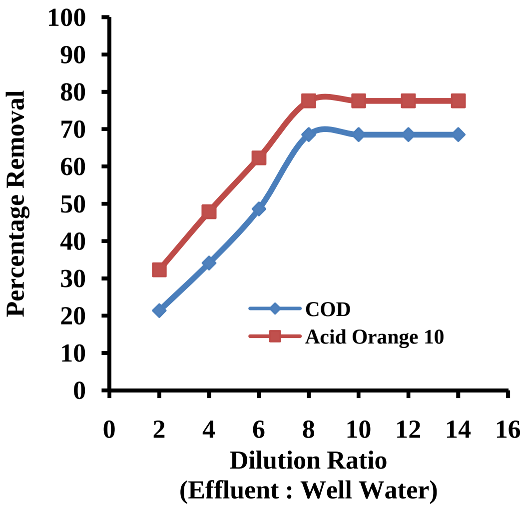

Fig. 2 The Percentage Reduction of COD and Color in a Textile Industry Wastewater using *Lemna minor* L. against Dilution Ratio

The results revealed that the percentage removal of the COD and color are low at the lower concentration and then increases later stages. In other words, the active sites in the *Lemna minor* L. could not be effectively utilized by the COD and color for their removal at the beginning and thereafter, active sites of *Lemna minor* L. could be effectively utilized. Up to dilution ratio of 8, the removal of various parameters in a textile industry wastewater by *Lemna minor* L. increased steadily and in the dilution ratio 10, 12 and 14, the percentage removal results showed the resembles of the results obtained for the dilution ratio 8. Hence, the optimum dilution ratio found in this study for the maximum removal of COD and color in a textile industry wastewater is 8.

At a low dilution ratio, the removal of COD and color in a textile industry wastewater was not absorbed easily by the *Lemna minor* L. This is because, at low dilution ratio, the ions do not freely move within the solution results not easy to absorb more on to the *Lemna minor* L. active sites. Similarly, the removal percentage for COD and color was higher for the higher dilution ratio; it is more likely that a significant portion of the available active sites is discovered, leading to higher specific uptake for the dilution ratio 8, 10, 12 and 14. The maximum removal percentage for COD and color in a textile industry wastewater by *Lemna minor* L. against dilution ratio found in this study is 68.54 and 77.58 % respectively (Fig. 2), which was obtained from the optimum dilution ratio of 8.

C. Verification Experiment

In order to validate the above experiments for reducing COD and color in a textile industry wastewater, a separate experiment has been performed with an optimum nutrient dosage (50g) and optimum dilution ratio (8) against pH (8) and contact time (4 days) for the removal of color in an aqueous solution. The initial concentration of color in an aqueous solution is similar to the initial concentration of color in a textile industry wastewater. The concentration of color in an aqueous solution was prepared by adding 45 g of Acid Orange 10 (Azo dye) in 1000 ml of deionized water.

The maximum removal percentage of color in a textile industry wastewater and in an aqueous solution by *Lemna minor* L. is shown in Fig. 3. The results (Fig. 3) showed that the maximum removal percentage color in an aqueous solution by *Lemna minor* L. is about 86.35%, which was higher than the removal percentage of color in a textile industry wastewater, where the removal rate is 82.85%.

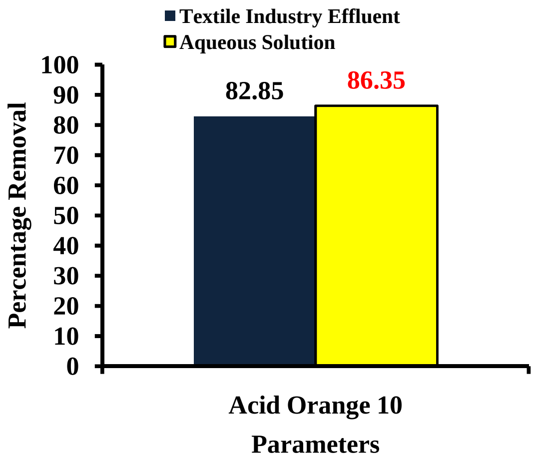

Fig. 3 The Percentage Reduction of Color in a Textile Industry Wastewater and in an aqueous solution using *Lemna minor* L. against Optimum Nutrient Dosage (50 g), Dilution Ratio (8), pH (8) and Contact Time (4 days)

The maximum removal rate in an aqueous solution is due to there were no competitive ions present in an aqueous solution than in a textile industry wastewater. Based on the results, it may be concluded that *Lemna minor* L. may be used for removing any other parameters in any type textile industry wastewater for an identified optimum value of selected parameters.

D. Model Development

In this study, the experimental data were fitted with second order polynomial regression model. The polynomial models are used to estimate and predict the shape of response values over a range of input parameter values. Polynomial models are a great tool for determining which input factors drive responses and in what direction. These are also the most common models used for analysis of designed experiments.

A quadratic (second-order) polynomial model for two explanatory variables has the form of the equation below. The single x-terms are called the main effects. The squared terms are called the quadratic effects and are used to model curvature in the response surface. The cross-product terms are used to model interactions between the explanatory variables. The polynomial regression model is given by

$$y=a + bx + cx^2 \tag{2}$$

in which 'y' is predicted value parameters, 'x' is an experimental value of parameters, a, b and c are the constants.

The polynomial equation found from the experimental data for the removal of COD (3) and color (Acid Orange 10) (4) in a textile industry wastewater is

$$y=8.6+24.149x-2.1655x^2 \tag{3}$$

$$y=10.522+26.366x-2.3201x^2 \tag{4}$$

The second order polynomial regression model data are represented in Fig. 4 and the relationship between the experimental result and model result is shown in Fig. 5. The R^2 values obtained for COD and color from Fig. 5 is 0.9882 and 0.9874 respectively. From Fig. 5, it may be found that the second order polynomial regression model is fitted well with the experimental data. Thus, from the model studies (Figs. 4 & 5), it is concluded that the removal of color in a textile wastewater follows the second order polynomial regression model.

From Figs. 4 & 5, it may also be found that the ability of the second order polynomial regression model is used to describe the fitness of the experimental data of the present work and for any type of industrial treatment experimental values.

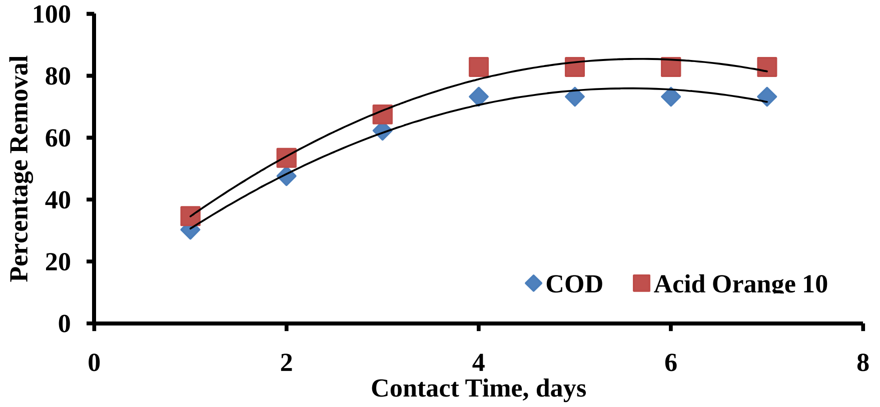

Fig. 4 The Second Order Polynomial Regression Model for COD and Color (Acid Orange 10) in a Textile Industry Wastewater for the Optimum Nutrient Dosage of 50 g, Optimum Dilution Ratio of 8 and pH of 8

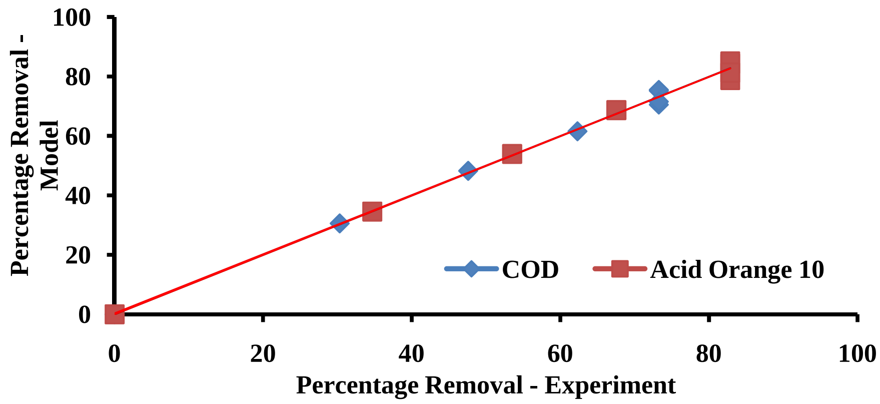

Fig. 5 The Relationship between Experimental Data and Second Order Polynomial Regression Model Data for COD and Color (Acid Orange 10) in a Textile Industry Wastewater for the Optimum Nutrient Dosage of 50 g, Optimum Dilution Ratio of 8and pH of 8

IV. Conclusion

In the present study, the experiments were conducted to find out the ability of *Lemna minor* L. for removing COD and color in a textile industry wastewater. The selected process parameters for this present study were nutrient dosages and dilution ratio against pH and contact time. The maximum percentage reduction of COD and color in a textile industry wastewater by *Lemna minor* L. were obtained at an optimum nutrient dosage of 50g and dilution ratio of 8 against the pH of 8 and contact time of 4 days. From the validation experiments, it was found that the experiments were reproduced at an optimum value found from the experiments conducted for removing COD and color in a textile industry wastewater. From, the model analysis, it was found that the first order kinetic model is fitted well with experimental data of COD and color in a textile industry wastewater. Finally, this study concluded that *Lemna minor* L. might be used for removing not only COD and color, but various parameters in a selected textile industry wastewater and in any type of textile industry wastewater.

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