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Textile industry wastewater color removal using *Lemna minuta Lin*

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ABSTRACT

Textile industry processes are among the most environmentally unfriendly industrial processes, because they produce color wastewater that heavily pollutes the environment. Therefore, wastewater in a textile industry has to be treated before being discharged into the environment. In this study, experiments were performed to remove colour from a textile industrial wastewater in a constructed wetland using *Lemna minuta L.* for different process parameters nutrient dosage, dilution ratio, and pH against different contact time. The maximum percentage reduction of colour in a textile industry wastewater by *Lemna minuta L.* was obtained at an optimum nutrient dosage of 50 g, dilution ratio of 10, pH of 7 and contact time of 6 days. Similarly, experimental results were validated and the validation experimental results showed that the experiments conducted at the optimum values using *Lemna minuta L.* for the removal of color were reproducing capabilities. The model was developed to fit the experimental data and the results of the model indicated that the reduction of colour in a textile effluent follows the first order kinetic model. Finally this study concluded that *Lemna minuta L.* might be used for removing colour in a textile industry wastewater and can effectively be used for removing colour in other industrial wastewaters.

Keywords: Textile Industry Wastewater, *Lemna minuta L.*, Process parameters

INTRODUCTION

The textile industry created environmental problems that are mainly caused by discharges of wastewater. Textile industries consume a large volume of water, organic and inorganic chemicals for making various textile goods and as a result, large volume of wastewater discharged onto the land with or partially or without treatments (D.Sivakumar, 2012).The raw materials particularly dyes used in the textile industry determine the volume of water required for production as well as wastewater generation. The quantities and characteristics of wastewater discharged vary from mill to mill, which depends on the water consumption and the average daily product. The main characteristics of textile industry wastewater are pH, electrical conductivity, total dissolved solids, organic and inorganic chemicals, colour, chemical oxygen demand, chloride, sulphate, salinity and other solution substances (I.S.Irina, 2008). The wastewater generated from the various processing units in a textile industry are desizing, scouring, bleaching, mercerizing, dyeing, printing, and packing required huge amount of organic chemicals of complex structure (V.Smita, 2014).The wastewater discharged from the textile industries are exceeding the standard for discharge into receiving waters and hence, wastewater from the textile industries have to be treated before being discharged to the environment to meet permissible limit of wastewater discharge standards.

Many approaches have been taken to reduce water consumption by recycling the wastewater comes from the textile industries. Various methods, including aerobic and anaerobic microbial degradation (D.Sivakumar, 2014), coagulation (H.R.Guendy, 2010), absorption (D.Sivakumar, 2014), activated carbon (S.Syafalni, 2012), electrochemical processes (D.Dogan and T.Haluk, 2012) reverse osmosis (M.Ramesh Kumar, 2010) ozonation (H.R.Guendy, 2007), adsorption (D.Shankar, 2014; Sivakumar Durairaj and Shankar Durairaj, 2012), catalytic oxidation (F.H.Hussein, and T.A.Abass , 2010) and membrane processes (G.Abdulraheem, and O.Abiodun, 2012) etc. can be employed to remove various pollutants in a textile industry wastewater including colour removal.

However, their costs are high and most of them are difficult to use under field conditions, hence such a condition there is an urgent need to study natural, simple, and cost-effective techniques for controlling pollution from industrial wastewaters and treating such wastewater, such as phytoremediation. Phytoremediation is the utilization of plants accumulation capabilities to remove contamination from water, wastewater, soil and air (D.Patel, and V.Kanungo, 2010). In recent years, considerable attention has been focused on absorption process using aquatic plants because, it has more advantage than over conventional treatment methods include: low cost; high efficiency; minimization of chemical and biological sludge (R.Roy, 2010) The application of phytoremediation technology by duckweed in wastewater treatment and management is quite interesting and revealing. *Lemna minuta 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 waters and wastewaters.

There are several studies focused on removal colour from aqueous solution (D.Suteu, 2011). This study focused to remove colour in a textile industry wastewater rather than other parameters using *Lemna minuta L.* with the help of constructed wetland (G.D.Ji, 2007). The colour of the textile industry effluent is main parameter to be removed, because it contains different intensity of different dyes. The dyes and their breakdown products are toxic for living organisms and hence, the decolourization of textile industry wastewater before being discharged onto the land. The experiment results of colour removal in a textile industrial wastewater using *Lemna minuta L.* were verified with the colour removal in an aqueous solution using *Lemna minuta L.* for their reproducibility. Further, kinetic model was developed to fit the experimental data.

MATERIALS AND METHODS

Collection of *Lemna minuta L*: *Lemna minuta L.* is commonly known as smallest duckweed and has very small leaves and short roots. The leaves of *Lemna minuta L.* tend to be more ellipsoidal than those of *Lemna minor L.* and the plants do not stick together on the surface, behaving like individuals rather than as a mat. It is growing as small group, has bright green in colour. It is growing normally in lakesides, pools, ponds, ditches, slow-flowing streams; in regions with sub oceanic cool to moderately temperate climate. *Lemna minuta L.* is native to the eastern area of North America, western coasts of Mexico and spread in temperate zones of Central and South America. In the middle of 20th Century, it was introduced in several European countries. Currently it is also spreading over various countries like Afghanistan, North India, Kazakhstan, Nepal, North Pakistan, West Russia, Turkmenistan; Africa, South West Asia, Australia, Japan, and Pacific islands. *Lemna minuta L.* was collected from the local pond, which had no connection with any textile wastewater discharge points. The collected *Lemna minuta L.* was washed with deionized water and weighed. Further, the *Lemna minuta L.* was initially subject to stabilization in small plastic tanks containing well water and the same were preserved for 15 days period. In addition, these 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.

Collection of Textile Industry Wastewater: For the present study, textile industry wastewater samples were collected from the final clarifier of textile industrial wastewater treatment plant of Kanchipuram, Tamil Nadu, India with the help of airtight sterilized bottles. Then, took the wastewater samples to the Environmental Laboratory and they were stored in the refrigerator at a temperature of 278 K for analyzing various parameters like total dissolved solids (TDS), chemical oxygen demand (COD) and colour intensity in later stages. The collected wastewater of textile industry has mixed of 3 dyes namely Remazol black 5, Reactive violet 1 and Reactive yellow 145. The colour of the textile industry wastewater is also due to the presence of above dyes. In order to reduce the various parameters in textile industry wastewater, wetlands was constructed (plastic tanks) by using *Lemna minuta L.* and conducted the adsorption study with various nutrient dosages, dilution ratio and pH against contact time.

Absorption Experiments: For this study, *Lemna minuta 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 minuta L*. Approximately, 100 g of *Lemna minuta L*. was used in each experimental tank for this study. These experimental tanks were filled with textile industry wastewater of 1000 mL. Triplicate of each experimental setup was maintained. In order to reduce various parameters in a textile industry wastewater, the experimental setup (constructed wetland) were examined for a period of 7 days by 1 day intervals by using *Lemna minuta L*. and conducted the absorption study with various nutrient dosages (10, 20, 30, 40, 50, 60 and 70 g), dilution ratio (2, 4, 6, 8, 10, 12 and 14) and pH (4, 5, 6, 7, 8, 9 and 10).

The nutrient used in this study was activated sludge collected from municipal wastewater treatment plants, Koyambedu, Chennai. The dilution ratio was used such that 1 part of wastewater with various numbers of part of well water, thus, the ratio of 2, 4, 6, 8, 10, 12 and 14 represents these 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 the various parameters in a textile industrial wastewater before and after treatment with *Lemna minuta L.* was determined as per the standard procedure stipulated by APHA, 2005. The absorption removal percentage of various parameters by *Lemna minuta L.* was calculated by using the following formula:

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

in which C_1 is the concentration of the parameter before treatment with *Lemna minuta L.* and C_2 is the concentration of the parameter after treatment with *Lemna minuta L.* The characteristics of raw wastewater from textile industry wastewater are given in Table 1.

The absorbance of textile industry wastewater before and after treatment using *Lemna minuta L.* was determined by means of the Elico-UV spectrophotometer, SL 150 adjusted at λ_{max} (Fig. 1). By referring to the calibration curve of the absorbance, the percentage reduction of colour in a textile industry wastewater could be obtained. The absorbance and calibration curves are represented in the Fig.1 and Fig.2 respectively. From Fig. 1, it may be observed that upto some wavelength, absorbance increased with wavelength increased, beyond which, the absorbance decreased. The point at which the absorbance decreased is called point of deflection and the wavelength corresponding to the point of deflection is called maximum wave length. The observed maximum wavelength from Fig.1 is 506 nm. Fig. 2 indicated calibration curve for textile industry wastewater at a wavelength of 506 nm and it may be observed that as a dilution factor increased absorbance decreased linearly with R^2 value of 0.9987 and Fig.2 is used for finding the colour removal efficiency for different process parameters.

RESULTS AND DISCUSSION

The different process parameters like nutrient dosage, dilution ratio and pH were selected for conducting the constructed wetland absorption study using *Lemna minuta L.*to reduce colour in a textile industry wastewater along with TDS and COD measurement, which is used for checking the validity of colour removal experiment against different contact time.

Effect of Nutrient Dosage: Experimental investigations were conducted by changing the nutrient dosage from 10 g to 70 g with an increment of 10 g using *Lemna minuta L.* against the different contact time from 1 day to 7 days with an increment of 1 day. Fig.3 indicates the percentage reduction of colour in a textile industry wastewater using *Lemna minuta L.* against different nutrient dosage with a contact time of 6 days, dilution ratio of 6 and pH of 7. Since, day 6 is an optimum contact time found from this study, the results obtained on the day 6 was presented and the results obtained by the day 1, 2, 3, 4, 5 and 7 were not presented in this study. The results revealed that the percentage removal for the selected various parameters is low by *Lemna minuta L.*at low nutrient dosages and then increases with nutrient dosage. Initially, the absorption sites of *Lemna minuta L.* are not open properly to absorb colour in a textile industry wastewater. Later, absorption sites are opened largely because of greater growth of *Lemna minuta L.*, which can be achieved when *Lemna minuta L.* consumed more nutrients for its growth. Up to nutrient dosage 50 g, the absorption of color in a textile industry wastewater increased by *Lemna minuta L.* steadily and for the nutrient dosage of 60 g and 70 g, the percentage removal results showed the resemblance of the results obtained nutrient dosage 50 g. Hence, an optimum nutrient dosage found in this study is 50 g and the maximum absorption removal percentage of color in a textile industry wastewater by *Lemna minuta L.* against an optimum nutrient dosage of 50 g is 82.7 % (Fig.3).

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 minuta L.* and for the different contact time from 1 day to 7 day with an increment of 1 day. Fig.4 indicates the percentage reduction of color in a textile industry wastewater using *Lemna minuta L.* against different dilution ratio with an optimum contact time of 6 days, an optimum nutrient dosage of 50 g and pH of 7. As similar to effect of nutrient dosage, day 6 is found to be an optimum contact for the effect of dilution ratio. The results revealed that the percentage removal of colour in a textile industry wastewater is low at the less dilution ratio and then increases with high dilution ratio. The dispersion of dye in more in high dilution ratio than less dilution ratio, as a result, the maximum colour in a textile industry wastewater is adsorbed easily by *Lemna minuta L.* than high concentrated textile industry wastewater (real solution). In other words, the active sites in the *Lemna minuta L.* could not be effectively utilized for the removal of colour at the beginning and thereafter absorbent sites of *Lemna minuta L.* could be effectively utilized. Upto dilution ratio of 10, the absorption of colour in a textile industry wastewater by *Lemna minuta L.* increased steadily and the percentage removal for the dilution ratio 12 and 14, showed as similar to the results obtained by the dilution ratio 10. Hence, the optimum dilution ratio found in this study for the maximum removal of colour in a textile industry wastewater is 10 and the maximum absorption removal percentage of colour in a textile industry wastewater by *Lemna minuta L.* against an optimum dilution ratio of 10 is 88.2 % (Fig.4).

Effect of pH: Experimental investigations were conducted by changing the pH from 4 to 10 with an increment of 1 using *Lemna minuta L.* and for the different contact time from 1 to 7 days with an increment of 1 day. Fig.5 indicates the percentage reduction of colour in a textile industry wastewater using *Lemna minuta L.* against pH with an optimum contact time of 6 days, an optimum nutrient dosage of 50 g and an optimum dilution ratio of 10. The results revealed that the percentage removal of colour in a textile industry wastewater is low at the beginning and then high with pH increases. Up to pH of 7, the adsorption of colour in a textile industry wastewater by *Lemna minuta L.* increased steadily and for the pH 8, 9 and 10, the percentage removal results showed the resembles of the results obtained for the pH 7. Hence, the optimum pH found in this study for the maximum removal of colour in a textile industry wastewater is 7. For the pH of 7, the active sites in a *Lemna minuta L.* could be effectively utilized for the removal of colour in a textile industry wastewater. The maximum absorption removal percentage of colour in a textile industry wastewater by *Lemna minuta L.* against an optimum pH of 7 is found to be 94.6 % (Fig.5).

From Figs.1,2 and 3, it may be observed that the removal percentage colour in a textile industry wastewater was not significant even the contact time, nutrient dosages, dilution ratio and pH were higher, it is more likely that though sufficient contact time is available, a significant portion of the available active sites remain undiscovered, leading to lower specific uptake for the nutrient dosage of 60 g and 70 g, dilution ratio 12 and 14 and pH of 8, 9 and 10 against the contact time of 7 days. Thus, the maximum absorption removal percentage of colour in a textile industry wastewater by *Lemna minuta L.* for an optimum nutrient dosage, dilution ratio and pH against the optimum contact time of 6 days is found to be 94.6 %.

Verification Experiment: In order to validate the experiments conducted for the reduction of colour in a textile industry wastewater, a separate experiment has been performed with an optimum nutrient dosage (50 g), dilution ratio (10), pH (7) and contact time (6 days) for the removal of reactive dye in an aqueous solution. The aqueous solutions may be prepared by using three dyes namely Remazol black 5, Reactive violet 1 and Reactive yellow 145. The concentration of aqueous solution of each dye is equal to the same concentration of colour in a textile industry wastewater (32 mg/L). The colour intensity of Remazol black 5, Reactive violet 1 and Reactive yellow 145 in an aqueous solution using *Lemna minuta L.* against an optimum nutrient dosage (50 g), dilution ratio (10), pH (7) and contact time (6 days) was calculated with the help of the Elico-UV spectrophotometer, SL 150 adjusted at λ_{max} of 592 nm, 543 nm and 427 nm respectively (the procedure is same as that of Fig.1 and Fig.2). The maximum removal percentage of colour in a textile industry wastewater and in aqueous solutions (3 dyes) by *Lemna minuta L.* is shown in Fig.6. The results (Fig.6) showed that the maximum removal percentage colour in a textile industry wastewater by *Lemna minuta L.* is about 94.6 %, which was lesser than the removal of colour in aqueous solutions of Remazol black 5 (96.8 %), Reactive violet 1 (97.1 %), and Reactive yellow 145 (97.4 %). The maximum removal rate in aqueous solutions is due to there were no competitive ions presented than in a textile industry wastewater.

Model Development: In this study, the experimental data are fitted with first order kinetic model. The first order model is given by

$$-\frac{dC}{dt} = k_1 C \qquad (2)$$

on integration the Eqn.2 becomes

$$\ln\left(\frac{C}{C_0}\right) = -k_1 t \qquad (3)$$

where C_0 is the initial concentration of color in mg/L, C is the concentration color in mg/L at time 't', 't' is degradation time, days and 'k_1' is the first order rate constant, days^{-1}. The negative sign indicates as time increases the rate constant decreases.The first order rate constant was calculated from the slope of the straight line by least square fit (Fig. 7). The rate constant k_1 and R^2 values are presented in Table 2. The R^2 value for color in a textile industry wastewater 0.9896 (Fig. 7). This R^2 value indicates that the ability of the first order kinetic model in describing the kinetics of the present work. In other words, the model is fitted well with the experimental data. Thus, from the kinetic studies, it was found that the reduction of color in a textile effluent follows the first order kinetic model.

Table.1.The characteristics of raw wastewater from textile industry wastewater

Parameters	Concentration
Electrical Conductivity, µS/cm	4856
Total Dissolved Solids, mg/L	3107
Chemical Oxygen Demand, mg/L	3458
Sulphate, mg/L	758
Chloride, mg/L	332
Colour, mg/L	32

Table: 2. The kinetic parameter and the regression coefficient for removing colour in a textile industry effluent at an optimum nutrient dosage (50 g), dilution ratio (10), pH (7) and contact time (6 days)

Sl.No.	Parameters	k_1	R^2
1	Colour, mg/L	-0.2832	0.9896

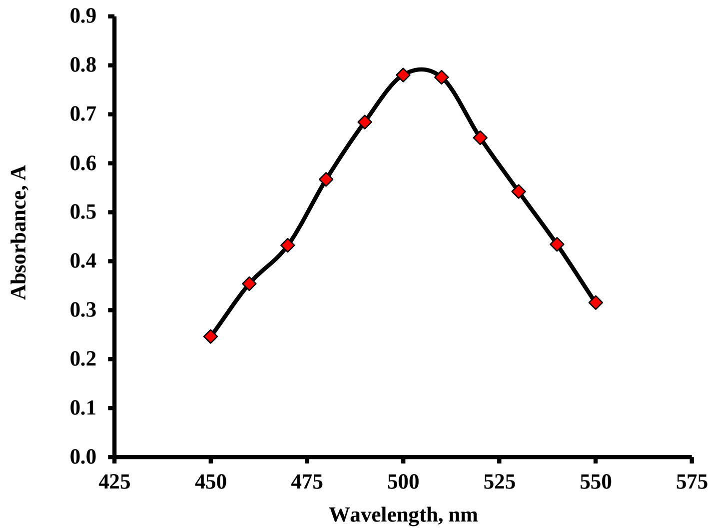

Fig.1. Absorbance curve for textile industry wastewater

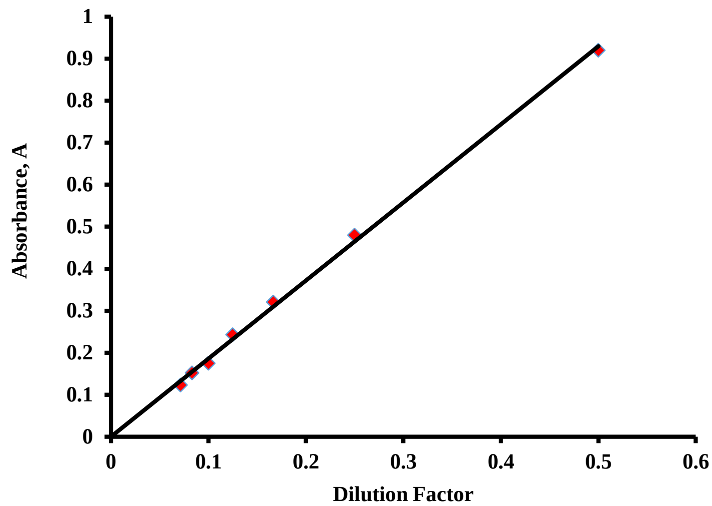

Fig.2. Calibration curve for textile industry wastewater at a wave length of 506 nm

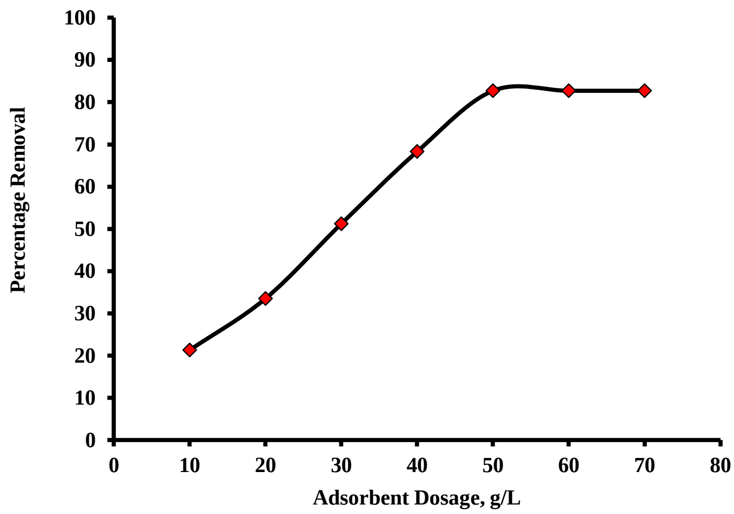

Fig.3. The percentage reduction of color in a textile industry wastewater using *Lemna minuta L.* against nutrient dosage

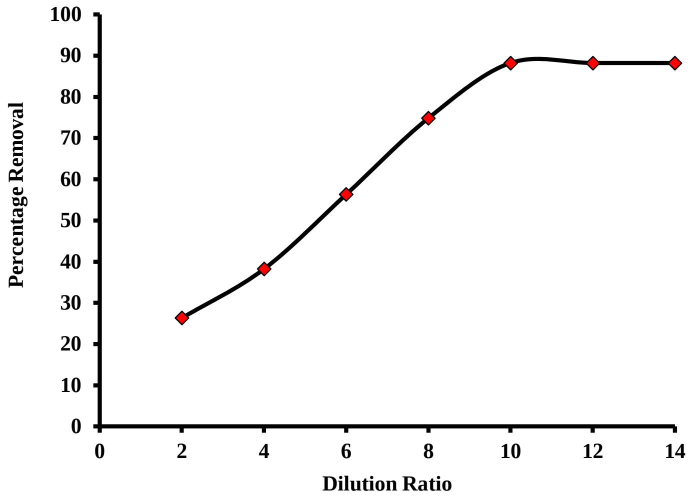

Fig.4. The percentage reduction of color in a textile industry wastewater using *Lemna minuta L.* against dilution ratio

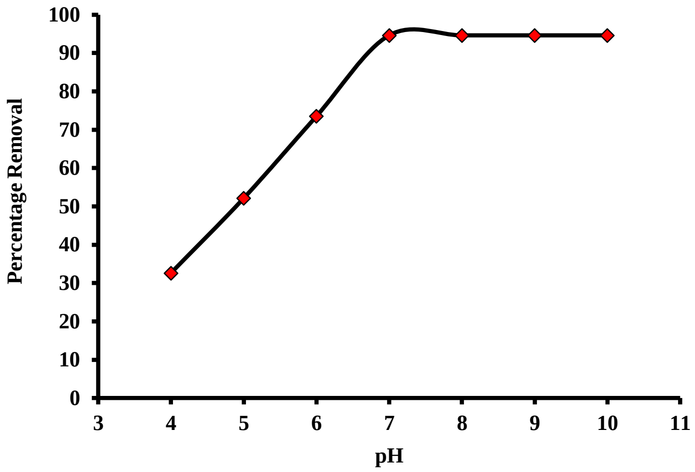

Fig.5. The percentage reduction of color in a textile industry wastewater using *Lemna minuta L.* against pH

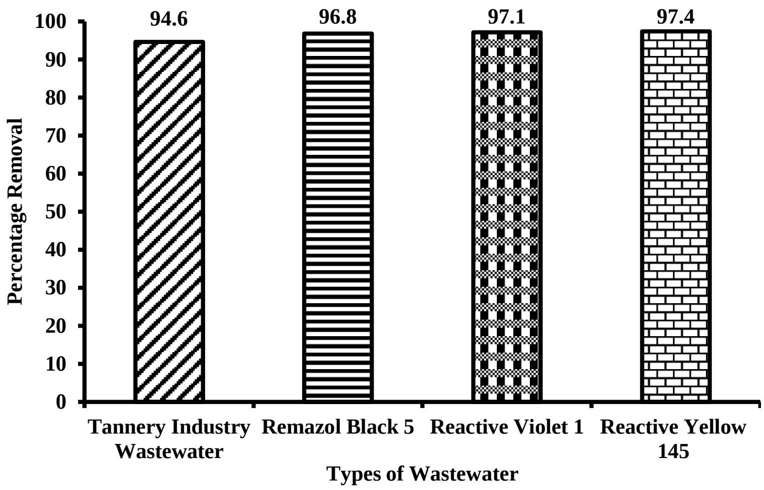

Fig.6. The percentage reduction of color in a textile industry wastewater and in an aqueous solutions using *Lemna minuta L.* against optimum nutrient dosage (50 g), dilution ratio (10), pH (7) and contact time (6 days)

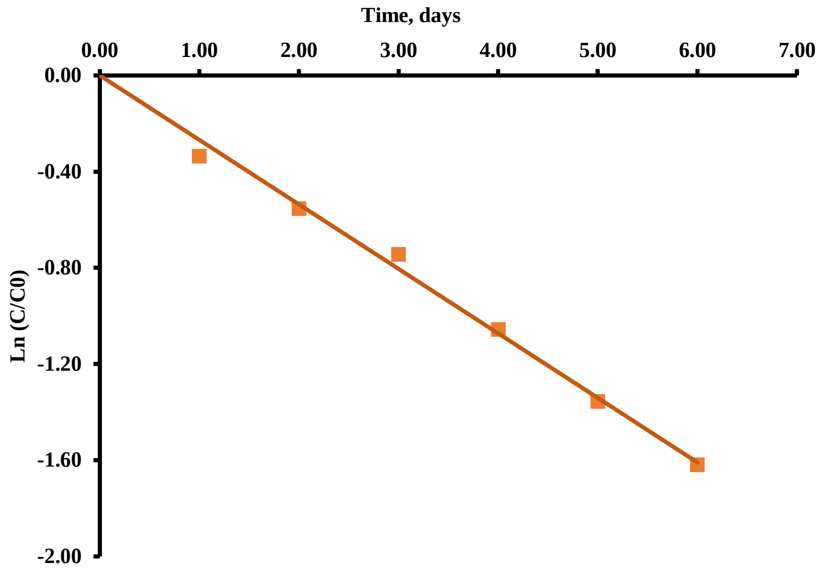

Fig.7.First order kinetic model for color removal in a textile industry effluent for the optimum nutrient dosage (50 g), dilution ratio (10), pH (7) and contact time (6 days)

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