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ORIGINAL ARTICLE

Ameliorative biodegradation of hazardous textile industrial wastewater dyes by potential microalgal sp.

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Abstract

The present study, BlackB133, RedF3b, RedH3BI and YellowME4GL textile dyes treated by three different algal species: *Desmodesmus* sp., *Scenedesmus* sp., and *Chlorella* sp., were investigated in batch studies to select the maximum degradation concentration. The COD 43 % for Black B133 dye and 37.4 % for RedF3B by *Scenedesmus* sp., 23.1 % for RedHE3BI and higher efficiency of 40 % for YellowME4GL by *Desmodesmus* sp., sulphates of efficiencies 84.2 % for Black B133 dye by *Desmodesmus* sp. About 87.51 % for RedF3B by *Scenedesmus* sp., 77.5 % for RedHE3BI by *Desmodesmus* sp., 77.6 % YellowME4GL by *Scenedesmus* sp. The phosphates 60 % for Black B133 by *Scenedesmus* sp., 67.07 % for RedF3B, higher efficiency of 89.9 % for RedHE3BI and 63.2 % for Yellow ME4GL by *Desmodesmus* sp. This study revealed a pathway for the subjectable concentration of microalgal degradation of dyes in industrial effluent treatment plant.

Keywords Batch studies · Degradation · Dyes · Microalgae · Wastewater treatment

1 Introduction

The industrialization of the globe is taken part in the production of highly toxic, mutagenic and xenobiotic in biosphere leads to the high rate of contamination. To drive a long-term solution for clean the wastewater environment from harmful hazardous contaminants removal is a critical process and challenging the problem which needs innumerable methods [1]. Larger quantity of wastewater was generated by the industry as many industries are dependent on the process that require large quantity of water for process thereby produces considerable amount of wastewater. Textile industry is the largest one among them and it is very intensive one. During the several production steps involved in fat, oil, colour and other chemicals as well as the draining wastewater must be cleaned from industry. The treatment process differs since the source of water used in the treatment and the treatment steps may vary can differ from each other. In large scale water treatment involves with different kind of pollutants, because of many cleaning and removing steps involved in the process of dying. While compare to the natural dyes, synthetic dyes are used in the textile industries because of ease in production, fastness, and variation in colour and discharging of untreated effluent containing harmful dye in millions of litres daily into water bodies posing to serious health problems [2].

A high amount of water is required for the colorization process that creates a significant volume of dye wastewater. Nearly, 200,000 tons textile dye was washed to effluents every year due to incompetence of dyeing process throughout the dyeing and finishing procedures and also not all the dyes are adsorbed to the dyeing material. Blue dye and red

Highlights
- *Desmodesmus*, *Scenedesmus*, *Chlorella* sp., are having efficacy in dye degradation.
- Electrical conductivity, BOD, COD shows significant dye degradation efficiency.
- Black, Red, Yellow dyes are degraded about 67.0, 89.9, 63.2 % by *Desmodesmus* sp.
- In future, evaluate the Microalgal sp. *in-vitro* study in Sewage Treatment Plant.

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dye have the largest and the most important class of industrial dyes. As additives, both the dyes are extensively used in paper industries, leather, plastic, as well as very familiar in the textile industries [3]. Photosynthetic algae are also water borne microbes found in the wide range around the globe. Azoreductase induces the dye degradation in algae was reported by many researchers. Algae are typically inhabited in wastewater and water resource environments to soil and various locations that are microscopic, photosynthetic organisms. Microalgae can be used, in order to treat these textile effluents and to degrade the dyes. *Chlorella vulgaris, Scenedesmus* sp., *Desmodesmus* sp., *Cosmarium* sp., *Sphaerocystis schroeteri, Chlamydomonas variabilis, Spirulina* sp., *Golenkinia radiate, Nannochloropsis oceanic, Chlorococcum humicola* etc., are the various types of algae which can be used for the treatment of dyes [2]. *Choleralla sp., Osicillatoria sp., Chlamydomonas pyrenoidosa* has the ability to transform the toxic aromatic amines into intermediate embolic compounds like water and CO_2, whereas *C. pyrenoidosa* has reported 94.19 % removal of methylene blue [4]. Also, the *Chlorella* species was used as food source by having high micro- and macro-nutrients; *Scenedesmus* sp., is used for biodiesel production; *Chlamydomonas variabilis* beneficial to biosorbent; *Spirulina* sp., has various utility in the medical field such as control diabetes, high blood pressure, and hypertension; *Golenkinia radiate* used as feed supplements or nutraceuticals. To design the future course of action regarding the environmental safety issues, an assessment on the toxicity of textile dyes towards aquatic algae is important due to the rapidly growing dye industries. The adoption of a proper treatment technology, evaluation of the effects of textile dyes on aquatic organisms are needed significantly [5].

Algae are having numerous groups of organisms, produced the pigmental chlorophyll to perform photosynthesis. It is used as the first option in biosorption and coagulation process, due to the constituents of lipids, polysaccharides, proteins, and various remarkable functional entities, *viz.* hydroxylates, carboxylates, phosphates, sulphates and amino structures. Hence, algae are used by most of the researchers to clear the pollutants present in the environment [6]. Due to their xenobiotic nature, these dyes are generally recalcitrant to biodegradation. Prior of discharging the effluents to the surrounding water bodies, it is mandatory to treat the dye bath effluents. The treatment should be economic and ecofriendly in addition to it. Generally, a high level of organics, inorganic nutrients abundant invading microbes, and hazardous materials are present in the untreated wastewater. Releasing of these wastewaters in water resources roots to the eutrophication and disposing the solid wastes in the landfills are leads to the contamination of surface water, groundwater contamination as well as the soil causative agents for the health and environmental hazards. This research paper focus on microalgae-based dye or textile wastewater treatment, since microalgae-based treatment is conventional and economical method. The present study is revealed that the novel organisms paying attention to the degradation of hard textile industrial wastewater dyes and purifying the wastewater. This study aimed at degrading Black b133, Red f3b, Red H3BI and YellowME4GL textile dyes by three different algal species, viz. *Desmodesmus* sp., *Scenedesmus* sp. and *Chlorella* sp. Batch studies were conducted to select the maximum degradation concentration by each species [6].

2 Materials and methods

2.1 Algae culture stock preparation

Three algae, namely *Desmodesmus* sp., *Scenedesmus* sp., and *Chlorella vulgaris* (cultures maintained at algal culture lab of CSIR-NEERI, Chennai Zonal Centre, Chennai, India) were grown in BG11 medium at optimal temperature of 21°C and with 1500 lux lightning condition.

2.2 Dyes mix preparation

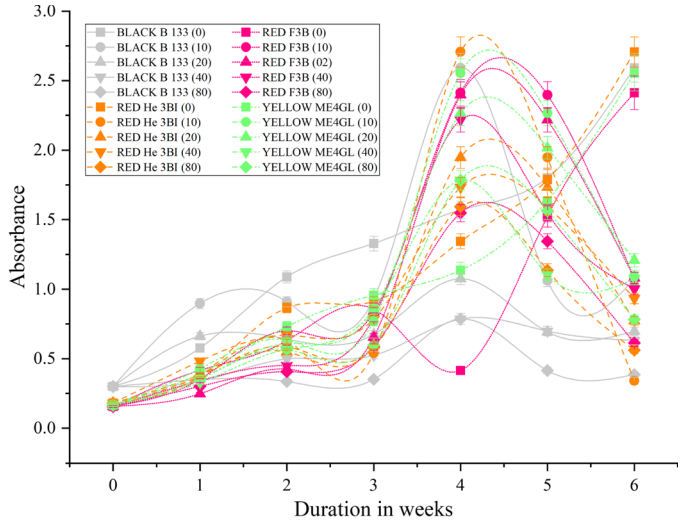
Four dyes, namely Blackb133, Redf3b, RedH3BI and YellowME4GL (99.9 %) (are purchased from local dye market of Kancheepuram, Tamil Nadu, India) were diluted in textile industrial water at various concentration of 10, 20, 40, 80, and 100 mg/L. The high concentration mix (100 mg/L) is taken as stock and subjected for the physiochemical studies. Then each concentration is inoculated with *Desmodesmus* sp., *Scenedesmus* sp., and *Chlorella vulgaris* microalgae, respectively. Microalgae in BG11 medium is taken as control.

2.3 Analysis of algal cell growth

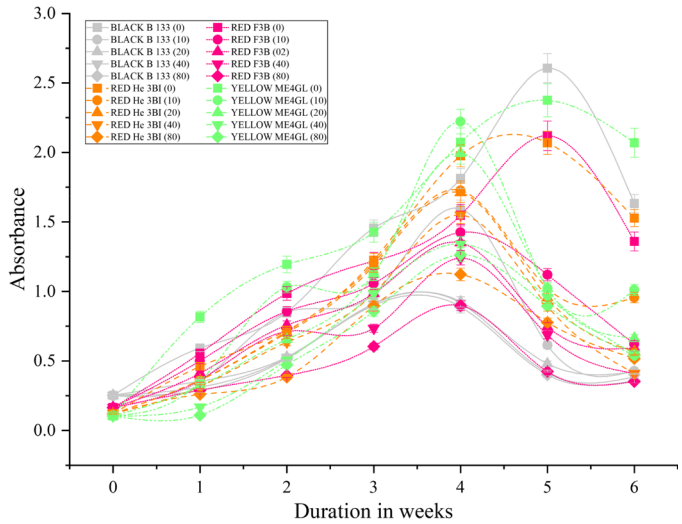
Double Beam UV-VIS Spectrophotometer (Systronics, Type: AU 2701) Spectrometer was used to identify the optical density (OD) of the microalgal suspension periodically at 7 days interval at the 7^{th}, 14^{th}, 21^{th}, 28^{th}, 35^{th} and 42^{nd} day at 680 nm wavelength [7].

2.4 Chlorophyll estimation

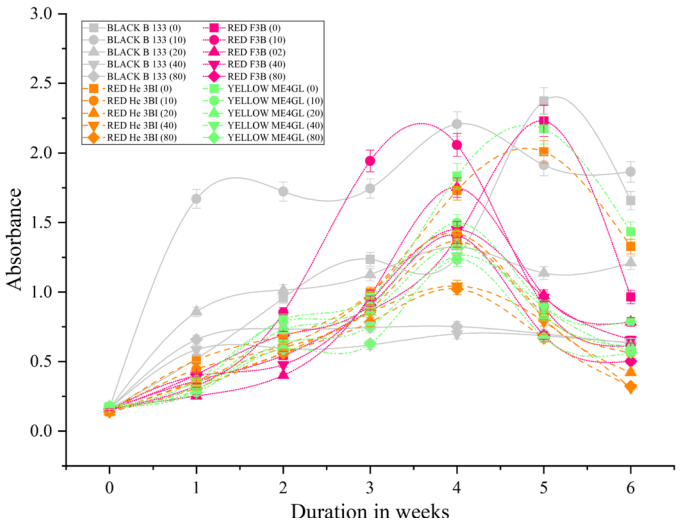
Extraction of chlorophyll from microalgae was carried by centrifugation of 3 mL microalgae cells at 5000 rpm for 5 mins and pellet was grounded and homogenized with 1 mL methanol (concentration 70 %, SRL Chemicals). The step is continued till the biomass of microalgae turns colourless. The supernatant was transferred to fresh vials and measured the spectra at 665 nm and 720 nm against the solvent (methanol) blank in the UV-spectrophotometer. The concentration



a Growth of *Desmodesmus* sp.,



b Growth of *Scenedesmus* sp.,



c Growth trend of *Chlorella vulgaris*

Fig. 1 Microalgae growth trends in response to the different dye and concentration. **a** Growth of *Desmodesmus* sp. **b** Growth of *Scenedesmus* sp. **c** Growth trend of *Chlorella vulgaris*

of Chlorophyll a (Chl a) was estimated by using the below equation [8]

$$\text{Chl a } (\mu g/mL) = 12.94\ (A_{665} - A_{720}).$$

2.5 Biomass estimation

Well grown algal cultures were centrifuged at 5000 rpm for at 15°C for 7 min to the collection of biomasses. The above step was repeated for twice with distilled water. Wet weight of biomass was noted, and cell pellet was dried in a vacuum desiccator which holds pressure of 720 mm Hg pressure at the maximum temperature of 40°C. Then dry weight of biomass was measured [9].

2.6 Protein estimation

Quantisation of protein was done by using following Lowry method [10] at the wavelength of 660 nm using spectrophotometer. Bovine Serum Albumin (BSA) as utilized as standard solution and Reagents A, B and C were prepared using BSA and Folin's reagent for estimating the presence of protein in the sample.

2.7 Physiochemical parameters

The dyes were subjected to physico-chemical tests likely as pH, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Dissolved Solids (TDS), Electrical Conductivity (EC), nitrates, sulphates and phosphates. The physicochemical parameters were estimated for the initial samples and final microalgae treated dye samples ForpH4500-H^+ B. Electrometric method was followed Electrical conductivity 2510 B laboratory method. Determination of total dissolved solids was done using 254°C method. Total dissolved solids dried at 180°C. To analyse BOD, 4500-O C method, the Azide modification procedure has been followed in which the sample and blank (dilution water) was incubated at 27°C for three days. Initial OD was measured for both blank and sample before three days and final OD was measured after three days. BOD is the difference between initial OD and final OD. The COD was quantified using 5220 B method. Open Reflux Method. COD was quantified using open reflux by stirring the sample with ferroin indicator and titrating against ferrous ammonium sulphate solution. The variation in the volume of blank and sample on titration is the measure of COD. Nitrates were determined by 4500-NO_3-B method. The Ultraviolet Spectrophotometric Screening method phosphates measured by 4500-P E method, the Ascorbic Acid Method and the amounts of sulphates were measured by 4500-SO_4^{2-} E method and Turbidimetric Method. The nitrates, sulphates and phosphates were measured by UV spectrophotometer. The Double Beam UV-VIS Spectrophotometer (Systronics, Type: AU 2701) were used at wavelength of 220 nm and 275 nm for nitrates, 880 nm for phosphates and at 420 nm for sulphates.

2.8 Dye degradation

The degradation of four types of dyes were estimated by UV spectrophotometer (Systronics model 2701) at the wavelength of 584 nm for BlackB133 dye, 561 nm for RedF3B dye, 559 nm for RedHE3BI dye and at 415 nm [11]. These wavelengths of the dyes were obtained by serial dilution of these dyes. The percentages of dye degradation were calculated by absorbance obtained from the above-mentioned wavelength of the initial diluted dyes and the final treated dyes. The formula used to calculate the percentage efficiency of dye is [11]

$$\%of\ efficiency = \left(\frac{initial\ concentration - final\ concentration}{initial\ concentration}\right) \times 100$$

3 Results and discussion

3.1 Cell growth

The microalgal density is proportional to the OD value of the population in the unit's cell protoplasm/volume or else considered as cell counts in the each microalgal species [7]. The growth of microalgae was monitored for six weeks at different concentration of the dyes at 1500 lux. The cell growth was found to be high in Black B133 at 80 mg/L concentration and 10 mg/L concentrations of Red F3B, RedHE3BI and YellowME4GL in *Desmodesmus* sp., whereas, in *Scenedesmus* sp., cell growth was higher in 10 mg/L of BlackB133, 40 mg/L of RedF3B, 80 mg/L of RedHE3BI and YellowME4GL. In *Chlorella vulgaris* growth was found to be high at 80 mg/L of BlackB133 and RedHE3BI dyes and 10 mg/L of RedF3B and YellowME4GL. The cell growth of the different dyes at various concentrations are shown in Fig. 1a, b and c. Due to insufficient nutrient supply and environment conditions, the growth of the algal cells was decreasing in the 5^{th} and 6^{th} weeks, hence, the study was curtailed at 6^{th} week of culture period. *Chlorella vulgaris* seems to have higher cell growth range than other two algal strains which is an evident from the data (Fig. 1c). The textile wastewater taken for treatment in five different dilutions, at 15 % (D1), 30 % (D2), 45 % (D3), 60 % (D4), 75 % (D5). The textile wastewater could not be used directly because of the microalgae growth can be seen at higher range in direct

usage of textile wastewater due toxicity of textile wastewater. The *Chlorella vulgaris* algae in BBM medium showed high growth rate in D1 on the 28th day, whereas in D3 and D4 limited growth was observed. Due to the presence of carbon, nitrogen, phosphorus, salt minerals in textile wastewater were found and intended to high growth of algae [12].

3.2 Chlorophyll estimation

Chlorophylls are participating in the major part of the photosynthesis process and the Chlorophyll molecule consist of a porphyrin ring as head, magnesium atom at centre and a long hydrocarbon phytol as tail and its connected by an ester bond. There are three types of pigments for microalgae, such as chlorophylls, carotenoids and phycobilin proteins. The Chlorophyll has two absorption bands, one at blue or green region ranges from 450-475 nm and other at red region ranges from 630-675 nm [13]. The Chl a ($C_{55}H_{72}O_4Mg$) with -CH_3 as the functional group it converts light energy into chemical energy hence it is considered as the light harvesting pigment. Another pigment Chlorophyll b (Chl b) ($C_{55}H_{70}O_6N_4Mg$) with -CHO as the functional group involves in helping the Chl a. The chlorophyll estimation of the various dyes for three algal strains are plotted in Fig. 2a, b and c. The chlorophyll of the diluted dyes showed its peak result in the third and fourth weeks, this shows that algal cells where active till the third and fourth weeks, due to the insufficient nutrients and environmental conditions the algae cells where inactive during the consecutive weeks since the line graph when in decremental order. In chlorophyll estimation *Scenedesmus* sp., showed the higher range in order of BlackB133 dye at 80 mg/L in the 6th week; RedF3B in 4th week; RedHE3BI in 6th week at 20 mg/L; whereas the Yellow ME4GL at 10 mg/L also in their 6th week. The lower range of chlorophyll were observed in *Desmodesmus* sp., for BlackB133 dye at 40 mg/L; RedF3B, RedHE3BI and YellowME4GL at 80 mg/L in their 1st week, when compared to other two species in their initial weeks. The chlorophyll content of the *Chlorella* Sp. has high concentration in the 5th week observation in RedF3B0 80 mg/L while comparing with the other species and dyes. The TDS was measured in four different dyes, such as BlackB133, RedF3B, RedHe3B1, and YellowME4GL. The *Desmodesmus* Sp., *Scenedesmus* Sp., *Chlorella vulgaris* are found maximum of 1400 TDS and minimum of 1100 and the actual dye was found at 800-400 mg/L (Fig. 3).

3.3 Biomass estimation

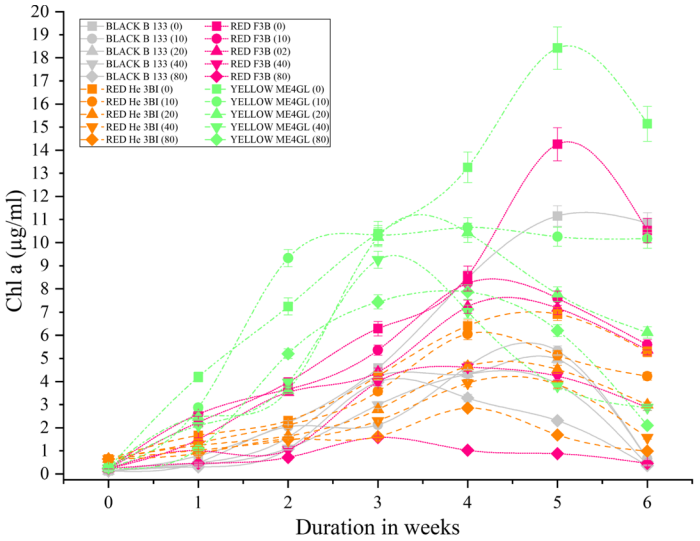
The biomass estimation of three algae strains at different dye concentration were shown in Tables 1, 2 and 3. The huge biomass was found in YellowME4GL dye in10 mg/L by *Desmodesmus* sp., and *Chlorella vulgaris* and 20 mg/L of YellowME4GL by *Scenedesmus* sp., by comparing the three algal strains. Whereas, the lower biomass was found at 80 mg/L of Blackb133 dye, by *Desmodesmus* sp., *Scenedesmus* sp. and *Chlorella vulgaris*. The YellowME4GL dye the algal species capable of producing voluminous biomass. The present study, algae has been utilised for degrading the dyes [14], after the maximum amount of degradation the biomass content remains settled in the dyes which can be separated from the dyes by simple process of drying. These algal remains can be used as a fertilizer for animals and as biofuels. Algae biofuels has not constituted any kind of sulphates or sulphur groups, they are non-hazardous as well as they are biodegradable. In existence, many microalgae are producing the fuel energy when compare to the fossil fuels [15]. Generally, in wastewater the biomass production of *C. vulgaris* and *P. subcapitata* algae was 1.11 and 0.72 gL^{-1}. Due to the water-borne bacterium in the wastewater environment, the biomass production of *P. subcapitata* and *C. vulgaris* by 46 % and 37 % respectively. The subsequent production was increased by the treatment of glucose and nitrates to the wastewater environment thereby increased the range about 61 % and 12 %, respectively [16].

3.4 Protein estimation

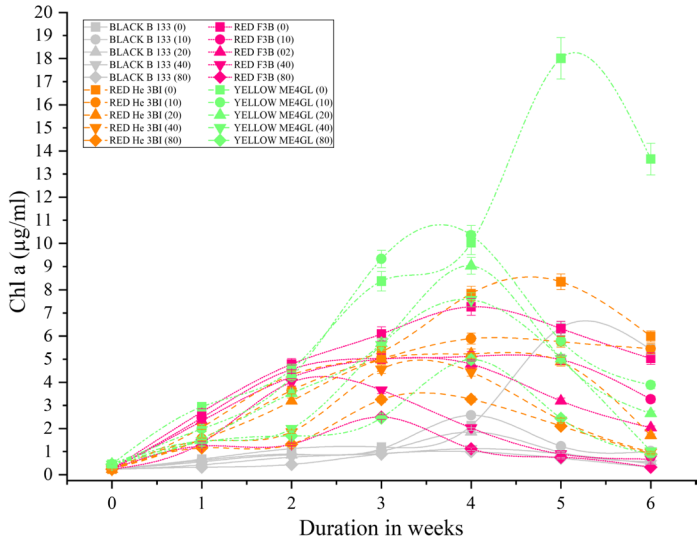
Figure 4 shows the protein estimation in three different algal strains of different dye concentrations. The maximum protein was estimated in yellow dye and minimal amount of protein was recorded in Black B 133 dye. In *Desmodesmus* sp., the maximum amount of protein was estimated in YellowME4GL at 20 mg/L and minimum in 80 mg/L of BlackB133 dye. In *Scenedesmus* sp., the minimum of protein was found in Red F3B at 40 mg and maximum of protein was estimated in 40 mg/L of YellowME4GL dye. In *Chlorella vulgaris* the minimum of protein was found in 20 mg/L of RedHE3BI and 40 mg/L of YellowME4GL dye. The protein concentration of *Chlorella pyrenoidosa* was determined in a closed system under controlled conditions like varying ammonium sulphate concentration, pH, solid load, incubation time, slurry to butanol ratio and enzymatic treatment to maximize protein concentration. About 78.1 % w/w protein concentration was obtained in middle protein concentrate phase, using these optimized parameters [17].

3.5 Physiochemical parameters

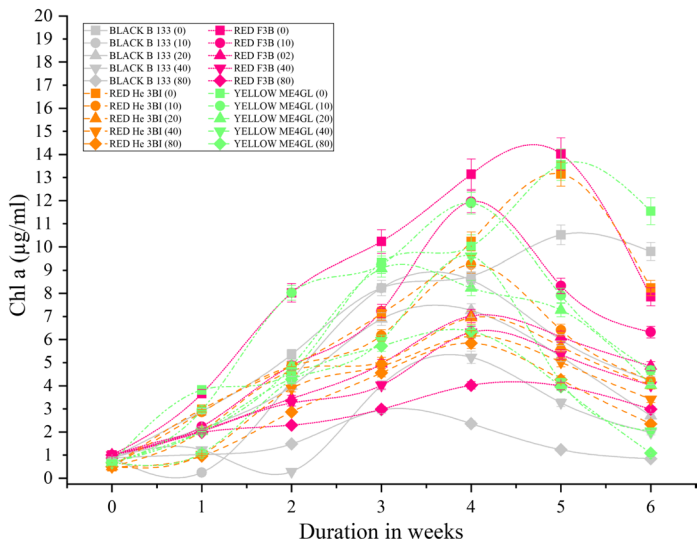
The degradation efficiencies were stated using several parameters such as pH varies from 6.19 to 8.05 for BlackB133 dye by *C. vulgaris,* 6.06 to 8.6 for RedF3B by *Desmodesmus* sp., 6.12 to 8.26 for RedHE3BI by *Desmodesmus* sp., 6.89 to 8 for YellowME4GL by



a Chlorophyll estimation of *Desmodesmus* sp.

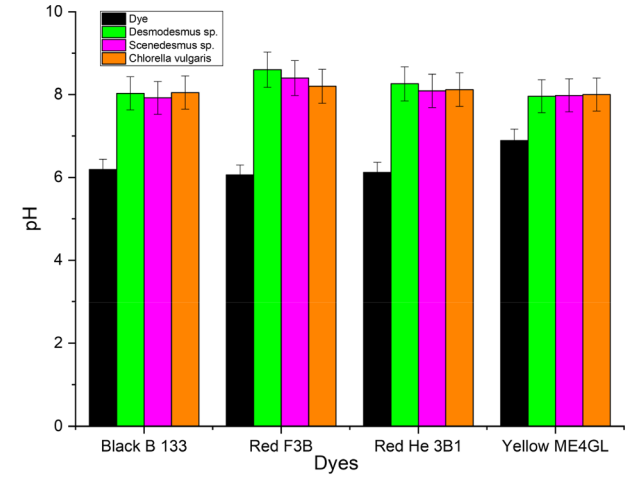


b Chlorophyll estimation of *Scenedesmus* sp.

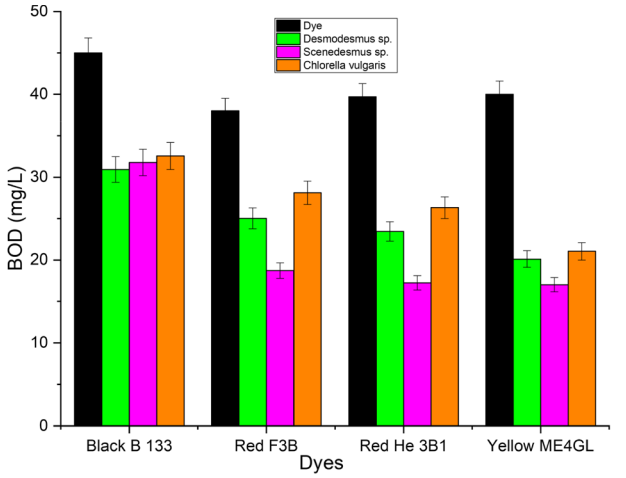


c Chlorophyll estimation of *Chlorella vulgaris*

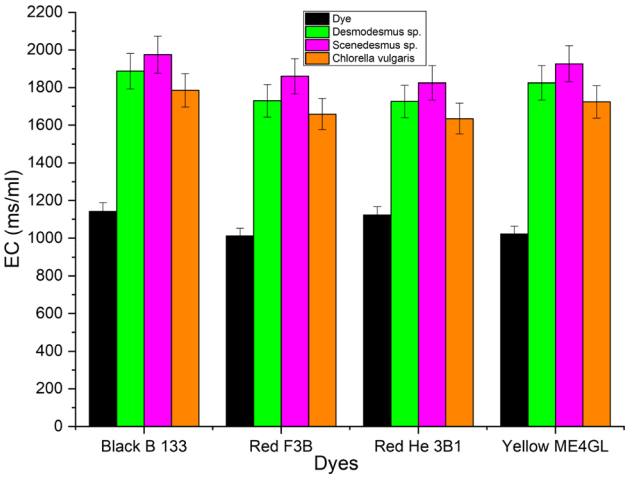
Fig. 2 The chlorophyll estimation of three algal strains. **a** Chlorophyll estimation of *Desmodesmus* sp. **b** Chlorophyll estimation of *Scenedesmus* sp. **c** Chlorophyll estimation of *Chlorella vulgaris*



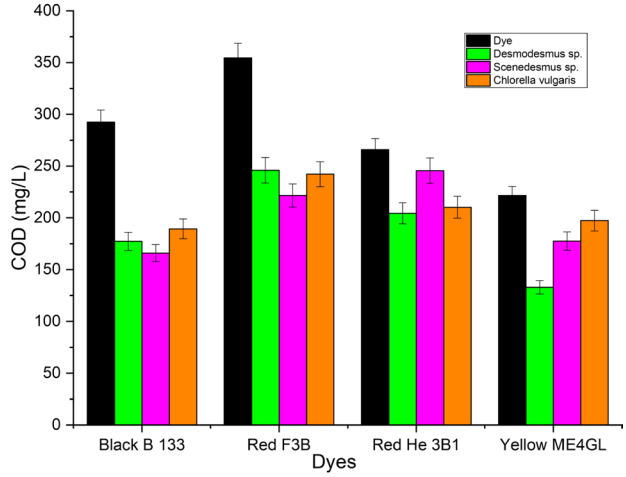
a pH of four dyes in three algal strains



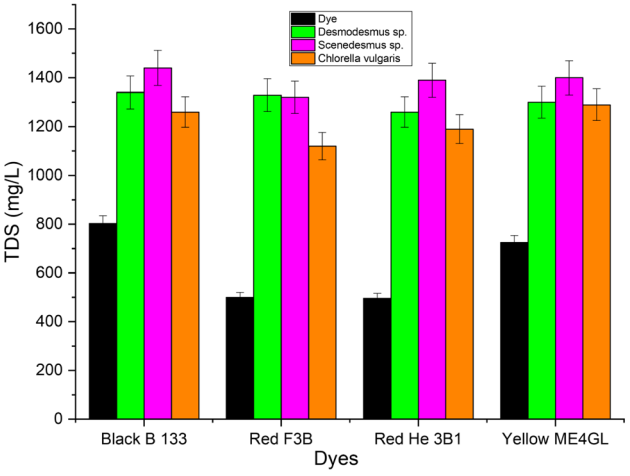
d BOD of four dyes in three algal strains



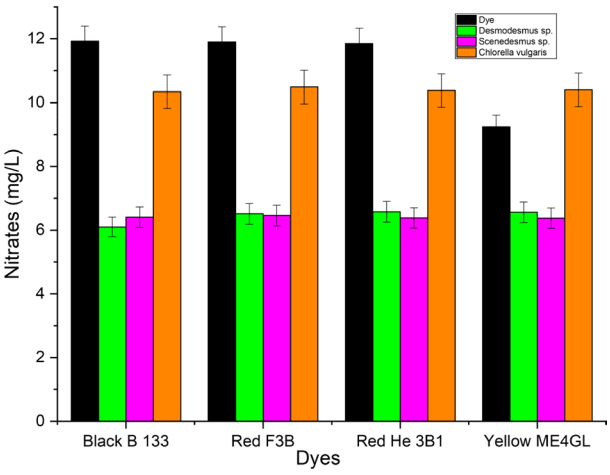
b EC of four dyes in three algal strains



e COD of four dyes in three algal strains

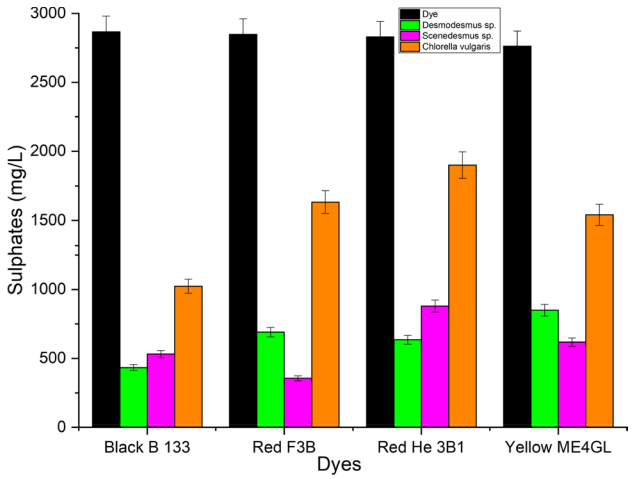


c TDS of four dyes in three algal strains

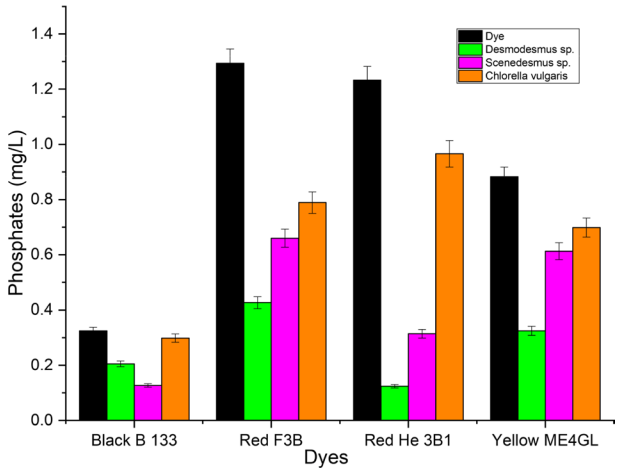


f Nitrates of four dyes in three algal strains

Fig. 3 The physiochemical parameters of three algae. **a** pH of four dyes in three algal strains. **b** EC of four dyes in three algal strains. **c** TDS of four dyes in three algal strains. d. BOD of four dyes in three algal strains. **e** COD of four dyes in three algal strains. **f** Nitrates of four dyes in three algal strains. **g** Sulphates of four dyes in three algal strains. **h** Phosphates of four dyes in three algal strains



g Sulphates of four dyes in three algal strains



h Phosphates of four dyes in three algal strains

Fig. 3 (continued)

Scenedesmus sp., *Desmodesmus* sp., for RedF3B showed the higher range of pH transformation whereas *Scenedesmus* sp., for YellowME4GL showed the lower range of transformation. In textile effluent, the pH transformation was found to be from 6.25±0.16 to 8.63±0.20 by *Chlorella vulgaris* [12]. The EC shows an efficiency of 42 % for Black B133, 45 % for RedF3B, 38 % for RedHE3BI and 47 % for YellowME4GL by *Desmodesmus* sp. Compared to other stains *Desmodesmus* sp., showed better reduction in YellowME4GL dye at 47 %. In treated textile effluent, EC was found at an efficiency of 83 % by *C. vulgaris* [12]. Among the three stains *Scenedesmus* sp., showed high BOD reduction of 29 % for BlackB133 dye, 52 % for RedF3B, 57 % for RedHE3BI and YellowME4GL. The highest range of reduction in BOD was seen in Red HE3BI and YellowME4GL at 57 %. The BOD efficiency was found to be 84.5 % in treated textile water effluent by *C. vulgaris*. *Spirogyra* showed an efficiency about 70.60 % in textile wastewater collected from ranipet [2]. COD reduction was observed 43 % for BlackB133 dye and 37.4 % for RedF3B by *Scenedesmus* sp., 23.1 % for RedHE3BI and 40 % for YellowME4GL by *Desmodesmus* sp. The efficiency COD reduction was high in BlackB133 dye at 43 % by *Scenedesmus* sp., 85 % of COD efficiency was observed in treated textile wastewater by *C. vulgaris* [12]. About 96.10 % of efficiency can be obtained by *Spirogyra* in the textile wastewater [2]. The sulphates reduction efficiencies were 84.2 % for BlackB133 dye by *Desmodesmus* sp., 87.51 % for RedF3B by *Scenedesmus* sp., 77.5 % for RedHE3BI by *Desmodesmus* sp., 77.6 % YellowME4GL by *Scenedesmus* sp. The sulphates *Scenedesmus* sp., has the higher efficiency for RedF3B at 87.51 %. The Cyanobacteria, diatoms, acid reducing bacteria, green algae, blue algae and can also be

Table 1. Biomass Concentration of Dye Treated upon *Desmodesmus* sp.

S. no.	Concentration (mg/L)	Biomass (g/L)			
		Black B133	REDF3B	REDHE3BI	Yellow ME4GL
1	0	1.425±0.012	1.473±0.025	1.510±0.008	1.592±0.075
2	10	0.985±0.018	1.386±0.024	1.459±0.004	1.501±0.065
3	20	0.925±0.011	1.327±0.032	1.382±0.014	1.496±0.019
4	40	0.856±0.024	1.274±0.027	1.398±0.057	1.320±0.016
5	80	0.653±0.031	0.987±0.051	1.182±0.066	1.29±0.021

Table 2. Biomass concentration of dye treated upon *Scenedesmus* sp.

S. no.	Concentration (mg/L)	Biomass (g/L)			
		Black B133	REDF3B	REDHE3BI	Yellow ME4GL
1	0	1.258±0.058	1.320±0.067	1.492±0.021	1.632±0.032
2	10	0.825±0.067	1.203±0.085	1.398±0.015	1.498±0.028
3	20	0.798±0.048	1.023±0.027	1.374±0.061	1.520±0.094
4	40	0.891±0.069	1.202±0.032	1.401±0.067	1.200±0.019
5	80	0.803±0.045	0.807±0.024	1.121±0.022	1.14±0.075

Table 3. Biomass concentration of dye treated upon *Chlorella vulgaris* sp.

S. no.	Concentration (mg/L)	Biomass (g/L)			
		Black B133	REDF3B	REDHE3BI	Yellow ME4GL
1	0	1.125±0.045	1.287±0.025	1.301±0.027	1.300±0.012
2	10	0.711±0.062	1.023±0.027	1.236±0.036	1.478±0.024
3	20	0.712±0.037	1.027±0.062	1.252±0.042	1.406±0.036
4	40	0.799±0.047	1.382±0.044	1.273±0.055	1.209±0.042
5	80	0.780±0.055	0.719±0.072	1.325±0.095	1.08±0.073

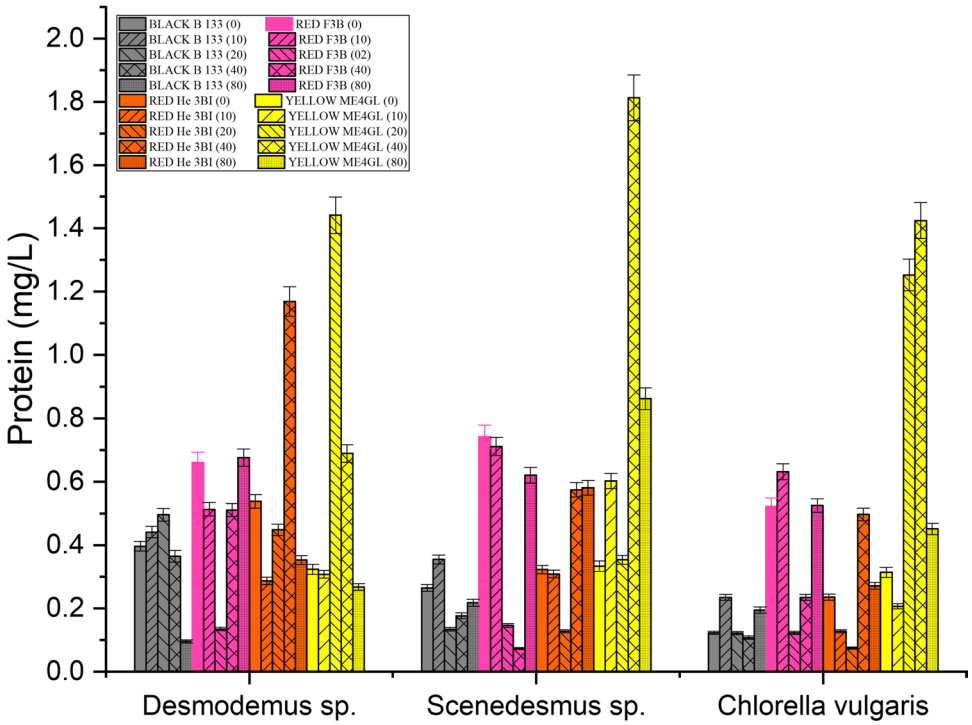


Fig. 4 Protein estimation of four dyes in three algal strains

used for removing sulphates in wastewater, sulphate having the significant removing ability about 46 % and the removal rate found at 0.56 g/L in a day has been obtained by RAB reactors [18]. The nitrate reduction was found at 48.79 % for BlackB133 by *Desmodesmus* sp., 45.68 % for RedF3B, 46.1 % for RedHE3BI, 37 % for YellowME4GL by *Scenedesmus* sp., *Desmodesmus* sp., had showed the highest efficiency in nitrate reduction about 48.79 % for BlackB133 dye. The high percentage flotation to recover biomolecules with ozonation and coagulation-flocculation may lead to the high-rate of nutrients removal by *Scenedesmus* sp. The complete NH_3-H removal was observed in cultivation of *Scenedesmus* sp. in wastewater which is achieved at 61 % of orthophosphate and 93 % of nitrogen removals [19] and phosphates about 60 % for BlackB133 by *Scenedesmus* sp., 67.07 % for RedF3B, 89.9 % for RedHE3BI and 63.2 % for YellowME4GL by *Desmodesmus sp*., 89.9 % for RedHE3BI by *Desmodesmus* sp., was the highest in the phosphate reduction. About 50 % of efficiency was given by *C. vulgaris* in textile effluent [12]. The degradation ranges of the three various algae are as shown in Fig. 3. *Desmodesmus* sp., showed higher rate of degradation in COD and phosphates, whereas *Scenedesmus* sp., showed higher rate of degradation in sulphates, nitrates and BOD. The efficiency of *C. vulgaris* in degradation is comparatively low when compared to other species. The decolourisation of malachite green using *Cosmarium* sp. was obtained at pH 9 which is basic in nature, yet the maximum discolouration was shown by *Desmodesmus* sp., at optimal pH range of 6.06 to 8.6. The physiochemical parameters of three algal strains in four different dyes are shown in Fig. 3. The degradation of all these physiochemical parameters shows that algae has influenced degradation levels, so that the characterisation of dyes has also decreased which indirectly decreases the toxicity of the dye effluents in the textile wastewater.

3.6 Dye degradation

Dye degradation by algal strains is carried by two pathways one by metabolic degradation and other method by metabolic biotransformation. Microalgal biodegradation is involved by families of Phase I and Phase II enzyme. Phase I enzymes like hydroxylase, carboxylases, monooxygenase, dioxygenases, and decarboxylases, which comprise the reactions like hydrolysis, oxidation or reduction process. In Phase II, the enzymes like glutamyl-tRNA dehydrogenase, superoxide dismutase, malate/pyruvate mono(di)oxygenase, malate/pyruvate mono(di)oxygenase, hydrolases, transferase, reductase, dehydratase, glutathione-S-transferases, catalase, pyrophosphase arboxylase/decarboxylase, alkaline and acid phosphatase are collectively participated in the biodegradation activity [20, 21]. Comparing the three algal strains, the maximum degradation was observed in BlackB133 80 mg/L (84.28 %), followed by RedHE3BI 80 mg/L (63.89 %), YellowME4GL 80 mg/L (59.87 %) and RedF3B 80 mg/L (48.78 %) by *Scenedesmus* sp. In *Desmodesmus* sp., degradation rate was high at RedHE3BI 80 mg/L (64.92 %) followed by BlackB133 80 mg/L (64.38 %), YellowME4GL 80 mg/L (54.74 %) and RedF3B 80 mg/L (48.4 %), whereas in *Chlorella vulgaris* at RedHE3BI 80 mg/L (66.12 %), BlackB133 80 mg/L (65.28 %), YellowME4GL 80 mg/L (54.23 %) and RedF3B 80 mg/L (47.3 %). Comparing the four dyes at various concentrations, the maximum degradation was found in BlackB133 by *Scenedesmus* sp., at 40 mg/L (97 %), 80 mg/L (84.37 %), by *Desmodesmus* sp., in 10 mg/L (60 %) and by *Scenedesmus* sp., at 20 mg/L (50 %) concentrations. At 10 mg/L concentrations, the minimum degradation was found in RedHE3BI dye (65 %) by *Chlorella vulgaris*, at 20 mg/L in RedF3B (10 %) *Scenedesmus* sp., at 40 mg/L YellowME4GL (15.2 %) by *Chlorella vulgaris*, at 80 mg/L RedF3B (48.75 %) by *Chlorella vulgaris*. The dye degradation of three algal strains are shown in (Fig. 5). The colour removal efficiency differs types of algae sp. and their growth rate and the molecular entity of the dyes from 4 % to 95 %. The industrial dyes have performed their decolourisation with basic cationic and basic fuchsin and removing the colour intensity and removes the methyl red up to 82 %. However, there was some fluctuations in the decolourisation of the orange II and G-Red, *C. vulgaris* showed algal activity to remove 43.7 and 59.12 %, 5.02 and 3.25 % were removed by *V. aureus* of the added dyes, respectively, 72 and 71 % at the same order induced the algal azo dye reductase enzyme in the treatment of either *C. vulgaris* with G-Red or methyl red [22–24]. Although, the additional factor that algal species enhancement and biomass production is related to the photosynthetic activity of the algal species. Treatment of textile wastewater using algae is cost-effective and the treated wastewater can also be reused. The assessment of mono Azo dye, tectilon yellow2G (TY2G), by *C. vulgaris* was in quested. As well as *C. vulgaris* acclimation has increased the COD efficiencies to increase to 88, 87, 89 % [25–27]. From the past researches, the selected algal

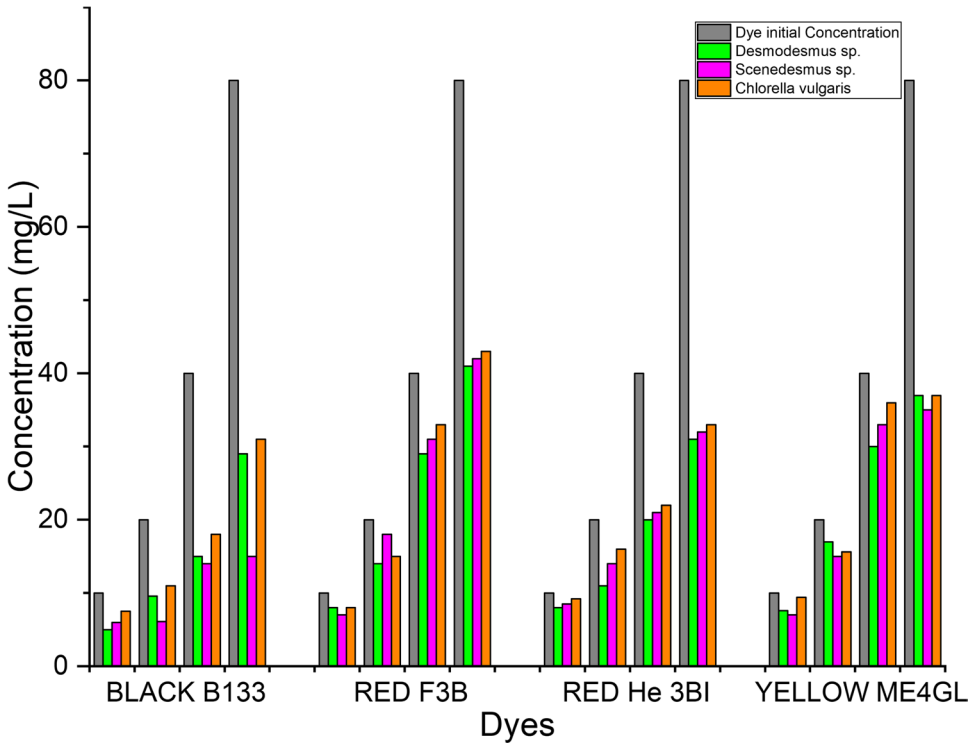


Fig. 5 Dye degradation of four dyes in three algal strains

sp. is more prompt to the dye degradation significantly. Thus, the selected microalgal *Desmodesmus* sp., *Scenedesmus* sp., and *Chlorella* sp., are having the potentiality in degrading the industrial wastewater dyes at their significant rates. The present study is suggested that, the selected algal sp. can be used in industrial level mass production in the large-scale fermentation and there by control the wastewater dyes produced from the textile, plastics industries, etc.

4 Conclusion

The dyes BlackB133, RedF3B, RedHE3BI, YellowME4GL with three different strains *Desmodesmus* sp., *Scenedesmus* sp., and *C. vulgaris*, *Scenedesmus* sp., are found to be tool for the bioremediation of textile wastewater based. Comparing the four dyes at their various concentrations, the maximum degradation was found in BlackB133 by *Desmodesmus* sp., in 10 mg/L (60 %) and by *Scenedesmus* sp., at 20 mg/L (50 %), 40 mg/L (97 %) and 80 mg/L (84.37 %) concentrations. These reactive organic dyes, COD, degradation efficiency were found highest at 40 %. The maximum degradation was found in YellowME4GL dye, at sublimated higher concentration. The maximum degradation efficiencies were stated by comparing the degradation capacity of several parameters such as pH from 6.06 to 8.6, EC at 42.17 %, BOD at 57.45 %, COD at 40 %, sulphates at 87.51 %, nitrates at 48.79 % and phosphates at 60.81 %. It can be concluded that, algae-based treatment systems are cost effective and easy handling procedures which can be implemented in larger scale to yield better efficiencies. The treated textile industrial wastewater (or effluent) after treatment may be reused or released in the environment to a sanitary sewer or surface water. In this study, the various diluted dyes are carried out in batch studies investigation and the best degradation dyes and algal species can be further subjected for the reactor studies in large scale, which can be implemented at textile industries.

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Declarations

Conflict of interest Authors are not having any conflict of interest.

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