Journal of Algal Biomass Utilization
J. Algal Biomass Utln. - Copyright © PHYCOSPECTRUM
ISSN: 2229 – 6905

Bio-sorption of physico-chemical constituents in textile dyeing effluent using *Spirogyra gracilis* Kützing

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Abstract

Dyes are mostly used in large quantities for colouring processes in textile industries. During this process huge amount of water is consumed and released into environment which is harmful to the aquatic animals, plants and human beings. Various physico-chemical techniques have been employed for the removal of dyes from wastewater and these methods create a major problem in the disposal of the concentrated sludge. To combat this problem, algae have been used in the bioremediation of textile dyeing effluent which have attracted the researchers to great interest. The present work has been aimed for the characterisation of physico-chemical parameters such as colour, odour, temperature, pH, electrical conductivity, total suspended solids, total dissolved solids, total solids , chemical oxygen demand, total hardness, alkalinity, dissolved oxygen, biological oxygen demand, chlorides, sulphates, phosphates, nitrate, lead, chromium , zinc and oil and grease in the textile dyeing effluent. The results showed that the above physico-chemical parameters decreased when treated with *Spirogyra gracilis* which falls within the limits prescribed by BIS except dissolved oxygen.

Key words: Textile dyeing effluent, physico-chemical parameters, *Spirogyra gracilis*.

Introduction

The degradation of the environment is due to the discharge of highly polluted wastewater from the textile, leather, printing and plastic industries (Bhagirath and Reddy 2002). Millions of untreated effluents are discharged from textile industries which directly mixes into rivers and lakes and alters the pH, BOD, COD and colour of the water resources. Various physico-chemical methods are commonly used for the treatment of textile dyeing effluents, but these conventional methods are generally cost effective, less efficient and disposal of the secondary pollutants are difficult. Biotechnological approaches are suggested by scientists and industrialists to remove the pollutants from wastewater using microorganisms often in combination with physicochemical processes. Eco-friendly microbial decolourisation and detoxification has emerged as a viable attractive alternative to these physicochemical methods (Telke *et al.,* 2010, McMullan *et al.,* 2001 and Robinson *et al.,* 2001).

Now-a-days, many investigators have made search for the feasibility of using low cost and efficient adsorbents. The use of biomass as adsorbents for the removal of dyes also offers a potential alternative to existing methods for detoxification (Aksu, 2001). Bioremediation is a pollution control technology where the biological systems are used to drive the degradation or transformation of various toxic chemicals into less harmful forms. This natural process is expected to clean up the environment in an effective way, being an alternative to conventional remediation methods (Vidali, 2009). The main objective of this study is to reduce the physico-chemical levels of textile dyeing effluent using a dye tolerate algae *Spirogyra gracilis.*

Materials and Methods

The algal species (*Spirogyra gracilis)* was collected from natural pond near the textile dyeing industry and used immediately. The algal mats collected from the pond was dried, powdered and used for further analysis. The textile dyeing effluent was collected from a dyeing factory located at Veppampalayam, Karur district, Tamil Nadu. The effluent was collected at 30 days interval and stored at 4^0C for further analysis.

A pilot study was carried out with different concentrations (25%, 50%, 75% and 100%) of textile dyeing effluent and 1g of powdered algal biomass was added separately under aseptic conditions and incubated at room temperature for 4 days. The colour removal was efficient in 50% concentration of textile dyeing effluent and hence for further studies this concentration was taken.

Physico-chemical characterisation of raw and treated textile dyeing effluent

The raw and treated effluent were analysed for various physico-chemical characteristics. In the treated effluent, the biomass was separated by centrifugation at 12000xg for 15 minutes prior to analysis. The physico-chemical parameters such as colour , odour , temperature , pH , electrical conductivity , total suspended solids , total dissolved solids , total solids , chemical oxygen demand , total hardness , alkalinity , dissolved oxygen , biological oxygen demand , chlorides , sulphates , phosphates , nitrate , lead , chromium , zinc and oil and grease were analysed in the supernatant (APHA, 1998).

Results and Discussion

Physical characteristics of raw and treated textile dyeing effluent

The physical characteristics of raw and treated textile dyeing effluent was presented in Table 1.

Table 1 - Physical parameters of raw and treated textile dyeing effluent

S. No	**Physical Parameters**	**Textile dyeing effluent**		**BIS tolerance limits (1981)**
		Raw effluent	**Treated effluent**	
1	Colour	Dark violet	Light green	-
2	Odour	Bad odour	Objection able odour	-
3	Electrical conductivity (µS cm^{-1})	854	574	600
4	Temperature (^{0}C)	40	28	Should not be >5^{0}C above the receiving water temperature
5	Total suspended solids (mg/l)	235	90	100
6	Total Dissolved solids (mg/l)	8000	1900	2100
7	Total solids (mg/l)	8235	1990	-

All the values are mean of triplicates

Colour

The colour of the raw textile effluent was violet, whereas, the effluent treated with algae turned pale or light green. Colour is the first contaminant to be recognised tin wastewaters and has to be removed before discharging into water bodies. Colour is the major pollutant to textile sector and it serves as a guide in deciding the quantity of chemicals used for the removal of colour and ensures economical treatment (Manivasagam, 1987)

Colour present in dye effluent gives a straight forward indication of water being polluted and discharge of this highly coloured effluent can damage directly the receiving water (Rajeswari *et al.,* 2013). Siyanbola *et al.* (2011) reported that the presence of very small amounts of dyes in water is very visible and affects the aesthetic merit, water transparency and gas solubility in water bodies and can be toxic to aquatic flora and fauna and cause severe environmental problems worldwide. The removal of colour from wastewaters is often more important than the removal of the soluble colourless organic substances, which usually contribute the major fractions of the biological oxygen demand.

Presence of colour in the raw effluent of the present study coincides with the findings of the Ogunlaja and Aemere, (2009) and Arul *et al.* (2011) who observed the colour of textile dyeing effluent to be in brownish black and black respectively. The industrial effluents are coloured, turbid and they are highly resistant to biological activities. Photosynthetic activity was reduced due to the dark colouration and also the aquatic ecosystem can completely change (Kolhe and Pawer, 2011) which supports the present study.

In the present investigation, the colour of the textile dyeing effluent treated with algae was reduced which was in accordance with the findings of Vijayakumar and Manoharan (2012) who used *Oscillatoria brevis* and *Westiellopsis prolifica* for the removal of colour from the dyeing effluent.

Odour

Presence of foul smell in the wastewater is one of the main problems in textile industry. Odour first of all expresses and gives the definition of the aesthetic values of the effluent (Siyanbola *et al.*, 2011). The odour of the textile dyeing effluent was found to be pungent whereas the treated effluent had objectionable odour. Unpleasant odour may be due to the presence of volatile compounds. Similar results regarding the pungent odour in the textile dyeing effluent was reported by Arul *et al*. (2011) and Prasad and Bhaskara, (2011). Noorjahan (2011) used *Tilapia mossambica* for the treatment of textile effluent, who observed the odour of the treated textile effluent is offensive.

Electrical conductivity

Conductivity is measured to establish the pollution zone around an effluent discharge. Conductivity measurements are used routinely in many industrial and environmental applications as a fast, inexpensive and reliable way of measuring the ionic content in a solution Electrical conductivity is the capacity of water to conduct electric current which directly relates to the concentration of salts and metal ions dissolved in water (Ahmed,1995). The Electrical conductivity (EC) of the untreated and treated textile effluent was found to be 12.89 µS cm^{-1} and 3.66µS cm^{-1} respectively. Ahmed and Nizamuddin (2012) recorded highest value of electrical conductivity (2515µs cm^{-1}) in untreated textile dyeing effluent which is supportive for the present study.

The discharge of untreated textile effluent which has high EC value may cause osmotic stress at the root zone of plants, which makes it more difficult for a plant to absorb water for growth. High level of EC in untreated textile effluent leads to decreased crop production and also affects the soil structure and permeability (URL, 2011). Reduced level of EC was also reported by (Mohmood *et al.,* 2013) in textile effluent treated with microorganisms. *Oscillotaria* and *Nostoc* had remarkable effect on of EC value of municipal wastewater which was lowered down to its maximum level (98.1%) at final stage when compared to control. The algal species had shown approximately equal performance in decreasing the EC value during phycoremediation at lowest concentration of wastewater. The EC value of water is more or less liner function of the concentration of dissolved ions in it, therefore its measurements can be used as a quick way to locate potential water quality problems (Kumar and Chopra, 2012).

Temperature

Temperature is basically important for its effect on chemical reactions, reaction rate, aquatic life and the suitability of water for beneficial uses. Temperature of wastewater is commonly high because of addition of warm water from industrial activities (Sankpal and Naikwade, 2012). The temperature of the raw textile dyeing effluent was 40^0C whereas in treated effluent, the temperature was found to be 28^0C which was lesser than the limits prescribed by BIS.

Higher temperature is harmful to aquatic life and affects the metabolic activities. Temperature also affects the concentration of dissolved oxygen which can influence the activity of microorganisms in the water body (Murphy, 2011). Decomposition of organic matters by coliforms could lead to heat generation and this might have contributed to the high water temperature. High temperature in textile dyeing effluent of the present study also coincides with the results of Walkar and Barbate, (2011) who recorded 43^0C in untreated pulp and paper mill effluent. Release of waste water containing high temperature into the aquatic system can cause changes in the species of fish, reduce the solubility of oxygen and amplified odour due to anaerobic reaction (Akan *et al.*, 2008). Hussein (2013) recorded that the temperature of the textile effluent treated with rutile was found to be 30^0C, which supports the present study.

Total Suspended Solids (TSS)

TSS plays an important role in waste water treatment. Solids present in dissolved form in an effluent constitute TSS which is routinely used to assess the performance of conventional treatment processes and need for effluent filtration in reuse application (Sankpal and Naikwade, 2012). The total suspended solids in the raw textile dyeing effluent were 2000mg/l whereas the TSS of treated effluent was found to be 90 mg/l which was within the tolerance limit prescribed by BIS (100mg/l), for the discharge of effluent into inland surface water.

High amount of TSS present in the present study was also reported by Ajao *et al.*(2011) and Mohabansi *et al.* (2011) in raw textile dyeing effluent. High amount of TSS in textile effluent reduce the light penetration and decreases the photosynthetic rates of green aquatic macrophytic algal cells which served as good source of many invertebrates, also leads to depletion of oxygen level (URL, 2011). Similar reduction in TSS was also reported by Chitra *et al.* (2013) in textile effluent treated with *Chlorococcum vitiosum* which supports the present study.

Total Dissolved Solids (TDS)

The amount of TDS present in the raw textile effluent was recorded as 8000mg/l, which exceeded the tolerance limit (2100mg/l) prescribed by BIS and that of treated textile effluent was only 1900mg/l which the BIS limits. Higher amount of total dissolved solids are one of the major sources of sediments which reduce the photosynthesis. The decrease in photosynthetic rate reduces the DO level of wastewater which results in decreased purification of wastewater by microorganisms (Tyagi and Mehra, 1990).

High amount of TDS was reported by Rao *et al.* (1993) in textile dyeing effluent which may be in agreement with the present study. The presence of high amount of TDS in effluent affects the growth of the plant directly, soil structure, permeability and aeration. Elumalai *et al.* (2013) recorded the highest reduction (61.71% and 61.38%) of TDS in textile dye industrial effluent treated with *Chlorella vulgaris* and *Scenedesmus obliquus* respectively.

Total Solids (TS)

The total solids are the sum of values of total dissolved and suspended solids. Industrial effluent contains a variety of solid materials (Kolhe and Pawar, 2011). The total solid contents of the raw textile effluent were found to be 8235mg/l, whereas in treated effluent, it was found to be 1990 mg/l. Singh *et al.* (2013) observed that the raw effluent discharged from textile industry has 6510 mg/l of total solids which supports the findings of the present study. Sivakalai and Ramanathan (2013) observed the reduction of total solids in textile waste water treated using *Spirulina platensis* which supports the present study.

Chemical characteristics of raw and treated textile dyeing effluent

The chemical characteristics of raw and treated textile dyeing effluent was presented in Table 2.

Table 2 - Chemical parameters of raw and treated textile dyeing effluent

S. No	Chemical Parameters	Textile dyeing effluent		BIS tolerance limits (1981)
		Raw effluent	Treated effluent	
1	pH	9.5	8.0	5.5-9.0
2	Alkalinity (mg/l)	430	220	-
3	Total hardness (mg/l)	460	164	600
4	Dissolved oxygen (mg/l)	0.5	2.5	-
5	BOD (mg/l)	90	20.2	30
6	COD (mg/l)	571	238	250
7	Chloride (mg/l)	1298	645	1000
8	Sulphate (mg/l)	948	198	1000

9	Phosphate (mg/l)	2.18	1.27	5.0
10	Nitrates (mg/l)	80	38	50
11	Lead (mg/l)	1.3	0.05	0.1
12	Zinc (mg/l)	5.46	2.47	5.0
13	Chromium (mg/l)	6.3	1.8	2.0
14	Oil and Grease (mg/l)	14.7	2.5	10

All the values are mean of triplicates

pH

pH is the measurement of intensity of acidity or alkalinity and measures the concentration of hydrogen ion in a solution. It is evident from the table that the pH of the untreated textile dyeing effluent (9.5) was above the tolerance limits of (5.5-9.0) prescribed by the BIS for the discharge of industrial effluents. The pH of the treated textile effluent obtained in the present investigation was found to be 8 which were within the BIS limits.

The pH of the effluents affects the physico-chemical attributes of water which in turn adversely affects the aquatic life, plants and human beings. This also changes the soil permeability which results in polluting underground water resources (Buckly, 1992). pH is one of the important factor which serves as an index for pollution and it is the determinant for effluent treatment. The presence or absence of various ions can have the direct relation with the pH of the effluent. The changes in pH values of effluent can affect the rate of biological reactions and the survival of microorganisms. The release of effluent containing high pH in an aquatic system may reduce the fish production and also inhibits the growth of aquatic macrophytes (Edmund, 1998).

Higher pH was reported by Thorat and Wagh (1999) and Sivakumar *et al.* (2011) when they analysed tannery effluent and textile dyeing effluent respectively. Their findings were in accordance with the present study. Sheela et al. (2013) reported a high pH in untreated textile effluent which after treatment with *Chroococcus minutes* showed a decrease in pH. Similar such decrease was also observed in the present study in textile dyeing effluent treated with *Spirogyra gracilis.*

Alkalinity

Alkalinity has effect on the buffering capacity of the water systems and needs to be monitored in all cases which shows the capacity of wastewaters to neutralize acids, and is undesirable. Alkalinity is an estimate of the ability of water to resist change in pH upon addition of acid (Mohabansi *et al.,* 2011). Alkalinity of the raw textile dyeing effluent was found to be 430 mg/l whereas in the treated effluent it was found to be 220 mg/l which lies within the limits prescribed by BIS (270 mg/l). Mohabansi *et al.* (2011) reported higher level of total alkalinity in textile effluent which supports the present study. High alkalinity may indicate the presence of weak and strong base such as carbonates, bicarbonates and hydroxides which are used in the effluent. According to Singh *et al.* (1998) high value of alkalinity in textile dyeing effluent may lead to metabolic alkalosis by affecting the mucous membrane of grazing animals.

Total hardness

Hardness in industrial wastewater was due to the presence of dissolved salts of multivalent metallic ions such as calcium, magnesium and other mineral salts. The amount of total hardness in raw textile effluent was 460 mg/l, whereas in treated effluent it was found to be 164 mg/l which was within the limits prescribed by BIS. The level of total hardness in textile effluent was high which falls in line with the findings of Ohioma *et al.* (2009) who reported that the amount of total hardness in textile processing industries was 1050 mg/l. Boominathan (2000) and Olguin (2003) reported 70% reduction of calcium in the paper mill industrial effluent treated with *Spirulina platensis* which falls in line with the findings of the present study.

Dissolved oxygen

Dissolved oxygen levels in water body indicate the ability to support aquatic flora and fauna. Dissolved oxygen level between 5-8 mg/l is satisfactory for the survival and growth of aquatic organisms (Jindal *et al.,* 2013). In the present investigation there was no dissolved oxygen in untreated textile effluent whereas in treated effluent, it was found to be 2.5 mg/l. The lower dissolved oxygen may be due to the use of various organic chemicals in the textile industry. The decay of organic compounds consumes more oxygen and leads to decrease in DO level. Higher temperature of textile effluent also lowers the DO level and reduces the DO have adverse impact on all aquatic life (URL, 2011). Sheela *et al.* (2013) reported that the raw textile effluent had a decreased level of dissolved oxygen.

Henciya *et al.* (2013) observed the textile effluent treated with *Cyanobacterium* showed increased rate of dissolved oxygen. The photosynthesis process might have occurred at higher rate in the presence of light intensity and this could have increased the DO in textile effluent with *Cyanobacterium.* Similar such increase in DO was observed in textile effluent treated with *Phormidium valderianum* (Shashirekha *et al.* 2008) which supports the present study.

Biological Oxygen Demand (BOD)

BOD is defined as the amount of oxygen required by microorganism for the breakdown of simpler substances to decomposable organic matter present in textile waste water. It is also taken as a measure of the concentration of organic matter present in any water. The greater the decomposable matter present, the greater the oxygen demand and the greater the BOD values (Ademoro, 1996). BOD is an important indicator of organic matter which indicates the presence of easily biodegradable compounds such as carbohydrates and organic acids (Senhal *et al.,* 2002).

The amount of BOD present in the raw textile effluent was 90 mg/l, whereas in treated textile effluent it was found to be 20.2 mg/l, which was within the tolerance limits prescribed by BIS (30mg/l). High amount of BOD was also reported in textile dyeing effluent by Desai and Kore (2011), Trivedi *et al.* (1986) and Mahmood *et al.* (2005), which support the results of the present study. Excessive amount of BOD is harmful to aquatic animals like fish and microorganisms. If the BOD level is too high, the water could be at risk for further contamination interfering with the treatment process and affecting the end product (Singh *et al.,* 1998). The reduction in BOD was also reported in domestic waste water treated with *Aspergillus terreus* and *Chlorella vulgaris* which corroborates with the finding of the present study. Low value of BOD may be due to lesser quantity of total solids, suspended solids in effluent as well as to the quantitative number of microbial population (Avasan and Rao, 2001).

Chemical Oxygen Demand (COD)

COD determines the oxygen required for chemical oxidation of organic matter with the help of strong chemical oxidant. COD is used to measure the pollution of domestic and industrial waste water (Kolhe and Pawar, 2011). In the present investigation the COD estimated in raw textile dyeing effluent was 571 mg/l whereas in treated effluent it was found to be 238 mg/l which was below than the tolerance limits prescribed by BIS (250 mg/l). The high amount of COD may be attributed to high concentration of xenobiotic compounds, which remain unaffected by microflora (Garg and Tripathi, 2013). COD is useful in pinpointing the toxic condition and presence of biologically resistant substances (Kolhe and Pawar, 2011). Increase in COD was also reported by Nian *et al.* (2007) in textile dyeing effluent. The high level of COD can cause a substantial damage to submerged plant and also harms the aquatic life. The decrease in COD was also reported in textile dyeing effluent treated with *Spirulina platensis* (Sivakalai and Ramanathan 2013) which also supports the finding of the present study.

Anions (Chloride, Sulphate, Phosphate, Nitrate)

Table 2 shows the level of anions tested in raw and treated textile dyeing effluent.

Chloride

Chloride is one of the major inorganic anions in textile effluents which act as bleaching agents. The level of chloride in untreated textile effluent was found to be 1298 mg/l whereas in the treated effluent it was 645 mg/l which was with in the tolerance limits prescribed by BIS (1000 mg/l). Excess amount of chlorides in the effluent may harm the agricultural crops, kill some microorganisms which are important in some food chains of aquatic life (Nosheen *et al.,* 2000), affects the plants, leaf margins becomes scorched, smaller, thicker and overall plant growth is reduced (Rhoades, 2011).

Sulphate

Sulphate ion is one of the major anions occurring in natural water and also the industrial effluents are the major sources of sulphates to the receiving water. When the effluent was over loaded with organic waste to point that oxygen is removed, then the sulphate as an electron acceptor is often used for the breakdown of organic matter which may produce Hydrogen sulphate. The level of sulphate in raw textile effluent was found to be 948 mg/l whereas in the treated textile effluent it was observed as 198 mg/l which was lesser than the tolerance limits prescribed by BIS (1000 mg/l). Kumar and Chopra (2012) recorded very high reduction in sulphate content in municipal wastewater treated with microbiological technology.

Phosphate

The level of phosphates in the raw textile effluent was 2.18 mg/l whereas in treated effluent it was found to be 1.27 mg/l which was less than the tolerance limits prescribed by BIS (5 mg/l). High amount of phosphate content in the effluent may be due to the presence of inorganic and organic matter in dissolved and particulate forms also leads to oxygen reduction when released into water bodies and affects the aquatic organisms. High amount of phosphate content may lead to kidney damage and osteoporosis in human. Dubey *et al.* (2011) noted similar trend during phycotreatment of industrial effluents with blue green algae. However he recorded highest reduction in phosphate using *Nostoc, Oscillotoria* and *Glococapsa* as these algal species had good potential and tolerance to polluted water.

Nitrate

Nitrate was produced by the oxidation of nitrate nitrogen both in form of nitrate, nitrite or ammonia and the high nitrate level in textile wastewater could also lead to eutrophication effects particularly in freshwater (OEDC, 1982). The range of nitrate nitrogen in raw textile effluent was 80 mg/l, whereas in treated textile effluent, the level of nitrate was found to be 38 mg/l which was within the tolerance limits recommended by BIS (50mg/l). Tartte (2010) also observed effective removal of nitrogenous contaminants from wastewater using *Anabeana* and *Nostoc,* which supports the present study.

Heavy metals

The amount of heavy metals namely lead, zinc and chromium were found to be 1.3 mg/l, 5.46 mg/l and 6.3 mg/l respectively in untreated textile effluent, whereas in treated effluent, it was found to be 0.05 mg/l, 2.47 mg/l and 1.8 mg/l respectively, which was within the limits prescribed by BIS. High level of lead in the untreated textile dyeing effluent of the present study also coincides with the findings of (Ahmed and Nizamuddin2012) which support the present study.

The elevated level of lead in the untreated textile effluent causes reproductive damage in aquatic life, haematological and neurological changes in fishes and other animals. The presence of high amount of lead in waste water has become a major threat to plant, animal and human health due to its bioaccumulation tendency and toxicity (Onacea *et al.,* 2007). The high concentration of lead may be due to the use of lead nitrates as an oxidizing agent in textile industry. Lead is also used in textile industry to make textile treatment, matches etc, (Eagleson, 1993).

High amount of chromium in water is harmful for plant growth and development which includes alterations in the germination process as well as in the growth of root, stem and leaves, which may affect total dry matter production and yield. High chromium content has also detrimental effects on fish, wildlife and invertebrates (Arun *et al.,* 2005 and Eisler, 1986). Ahmed and Nizamuddin, (2012) reported that the amount of chromium present in the raw textile effluent was ranged from 0 to 0.1126 mg/l.

Oil and grease

Evaluation of oil and grease in effluent is necessary as they may interfere with biological processes leading to decreased efficiency of effluent treatment (Garg and Tripathi, 2013). The amount of oil and grease present in the raw textile effluent was 14.7 mg/l whereas in treated textile effluent, it was found to be 2.5 mg/l which was with in the tolerance limits prescribed by BIS (10 mg/l).

The presence of oil and grease in the industrial effluent was mainly due to the operation process. Industrial waste water contains high amount of oil and grease which may cause a serious problem when discharged into water bodies without treatment. Excess amount of oil and grease in the textile dyeing effluent in excess may interfere with aerobic and anaerobic biological process (Sagar *et al.,* 2012).

Conclusion

The physico-chemical characteristic of the untreated textile effluents was reduced after treatment with the *Spirogyra gracilis.* The result also indicates that *S. gracilis* might be an effective treatment for textile dye effluent. Thus, the present study clearly indicates that *S. gracilis* can be used as a good microbial source for effluent treatment.

Acknowledgement

The authers acknowledge Avinasilingam Institute for Home Science and highern Education for Women, India for their financial support to the work.

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