Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(6): 1169-1172
Received: 19-09-2018
Accepted: 21-10-2018

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Sustainable decolouration of dyes from effluent: A review

Aaditaa and Sakshi

Abstract
Dyes are natural or synthetic organic compounds which are used for coloring different products and materials. Many industries such as leather, paper, plastic, textiles use dyes in many of their processing operations. Among various industries, textiles ranks first in extensively using dyes for colouring materials such as fibres, yarns and fabrics. Dyes are considered as a most harmful environmental pollutant because a very small amount of dye in water changes its appearance, colour and taste. The presence of dye in effluent accelerates environmental problems, disturbs aquatic life and also destroys water quality. There are various conventional and traditional techniques used by many industries for removing dyes from effluents but due to the generation of huge amount of sludge and their high cost. The main constraints for their use are these processes are less economic and efficient. The present review highlights the various sustainable processes and techniques which utilizes low cost, recycled and ecofriendly materials for decolourising dyes from effluent.

Keywords: Dyes, decolouration, effluent, industries, sustainable

Introduction
Textile sector is one of the major contributors in Indian economy because of its high percentage of total export. Dyes are extensively utilized by textile industries, mainly for coloring the textile materials and their products. Textile industries are considered one of the major contributors of environmental pollution due to the production of huge amount of waste which mainly consists of dye effluent, salts, chemicals and other suspended solids. Synthetic dyes are widely used by industries as they are cheap, easy to handle and have high fastness properties. Some of synthetic dyes are carcinogenic in nature especially azo dyes which are mainly responsible for health problems among the textile workers. But due to high export demands of textile materials, textile producers are extensively using synthetic dyes. These synthetic dyes have complex aromatic structure which is resistant to light, ozone and other degradative agents (Joshi *et al*. 2004) [6].

In many industries there are conventional treatment plants or ETPs (Effluent Treatment Plants), but they generate high amount of sludge which is toxic and requires proper treatment and disposal. The ETPs installation is costly and many textile producers do not have sufficient funds to install such treatment plants. In order to overcome these limitations there are various physical, chemical and biological sustainable and economic techniques which are utilizing natural substances which are considered as waste after treatment such as orange peel, jackfruit seeds, cactus, banana peel, aloe vera leaves shell etc. for removing dyes from effluent. Various bacterias, fungi, algae are also used for dye removal from effluents.

The sustainable decolouration techniques can also be classified in similar way as conventional techniques such as physical, chemical and biological processes.

Physical Method of Dye Removal from Effluents
Physical techniques are those which removes colour from the effluent physically. Various physical sustainable techniques are as follows

Coagulation
Coagulation is the process in which the liquid changes to semi solid or solid state upon addition of coagulants such as $Al^{(+3)}$ and $Fe^{(+2)}$ salts.

The basic phenomena involved in coagulation is when the coagulants are added in water at a higher concentration they rapidly precipitate the impurities such as colour, TDS (Total Dissolved Solids), SS (Suspended solids) in the form of precipitate and settle down at the bottom of tank. The sludge which is settled down is again treated and disposed of in suitable conditions.

There are many natural coagulants which are also capable of removing dyes from effluent such as *Moringa oliefera*, various cactus species, tamarind seeds, corn cobs, green beans etc. These coagulants produce less sludge in comparison to synthetic coagulants and also have good dye removal efficiencies.

The study carried out by (Kalaicelvi *et al* 2016) [7] has utilized *Moringa oliefera* seed powder for removing colour. The chemical oxygen demand (COD) of effluent was checked. They also evaluated the removal efficiency of natural as well as synthetic coagulants. The seed powder was extracted by removing seed coats from the outer layer and after that seeds were thoroughly washed with freshwater and then dried in shade. After drying, the seeds are grinded into powder form and are sieved through stainless steel sieve. Then, the prepared powder was added in 1000ml effluent sample and low speed stirring is done for 1 minute followed by high speed stirring for 10 minutes. The mixture was allowed to settle for 30 minutes.

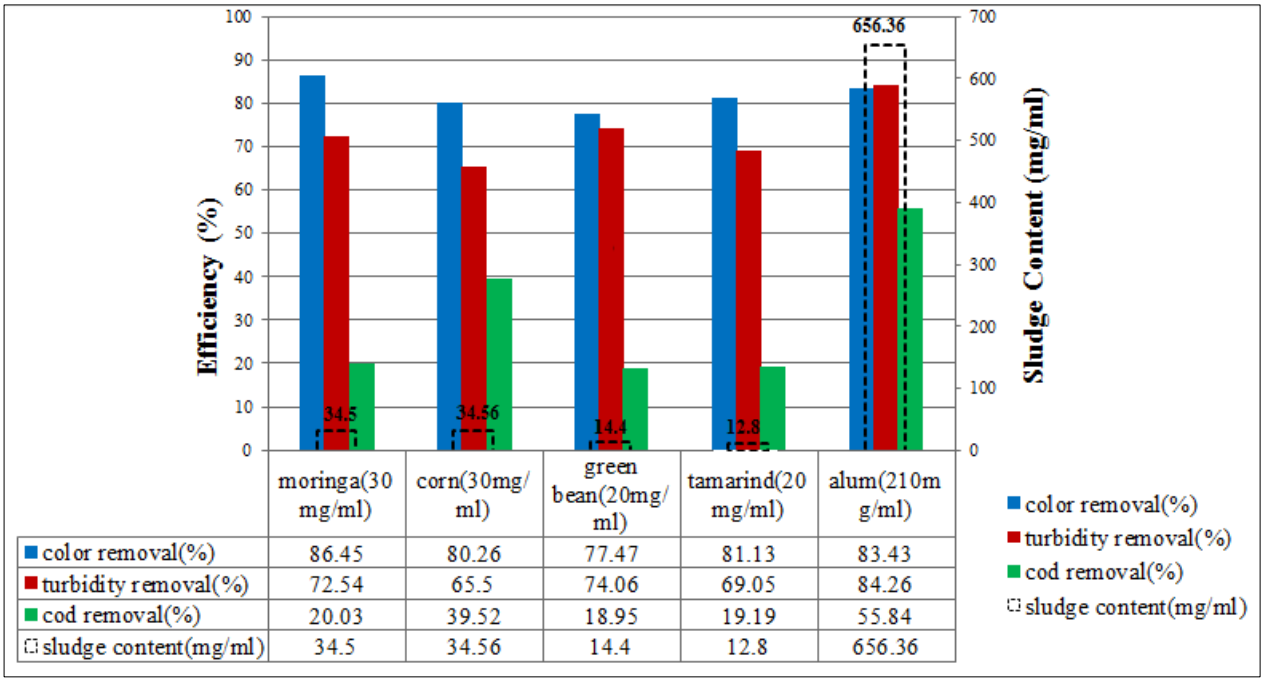
After 30 minutes, the solution was analyzed and compared with synthetic coagulants. The results revealed that *Moringa olifera* reduces the colour value of effluent (3960 pt co) to 1030 pt co in comparison to chemical treatment which reduces up to 860 pt co colour value. The *Moringa oliefera* showed somewhat equivalent colour removal efficiency in comparison to chemical treatment. In case of chemical oxygen demand (COD) of effluent sample i.e.1084mg/L. The *Moringa oliefera* showed higher efficiency in removing COD from effluent (724mg/L) as compared to synthetic coagulants (1296mg/L).

The cactus species i.e. *Opuntia Ficus Indica* was used as a natural coagulant in removing dyes from effluent, in the study conducted by Vishali and Karthikeyan (2014) [16]. They had used *Opuntia Ficus Indica* species as a natural coagulant for treating paint effluent. The cladode part of cactus was handpicked, crushed and dried in oven at a temperature of 100 ^{o}C for 2h. After preparing powder, that active component was extracted from it by mixing 3g of cactus powder in 0.17 g/L NaCl and was stirred for 50 minutes.

Then 50ml of prepared extract was added in 1L dye effluent and was agitated at 200 rpm for 2 minutes with a settling period of 60 minutes. The results revealed that 50 ml of coagulant volume show up to 90% removal efficiency for colour, COD and turbidity of textile effluent.

Charoenlarp and Prabphane (2015) [2] compared the performance of synthetic coagulant (alum) and natural coagulants such as *Moringa oliefera*, corn, green beans and tamarind seeds. All the coagulants were used with optimum conditions and their performance was compared on the properties of effluent such as colour, turbidity, COD removal and sludge content.

The results (Fig.1) showed that maximum colour removal efficiency was of *Moringa oliefera* seed powder followed by alum. Alum showed highest removal efficiency for turbidity and COD removal. Sludge content was very high in case of alum as compared.



	moringa(30 mg/ml)	corn(30mg/ml)	green bean(20mg/ml)	tamarind(20 mg/ml)	alum(210mg/ml)
color removal(%)	86.45	80.26	77.47	81.13	83.43
turbidity removal(%)	72.54	65.5	74.06	69.05	84.26
cod removal(%)	20.03	39.52	18.95	19.19	55.84
sludge content(mg/ml)	34.5	34.56	14.4	12.8	656.36

Fig 1: Comparison of performance of Different Natural Coagulants on Wastewater Treatment

(https://www.researchgate.net/publication/319872875_Ecofriendly_decolorization_of_textile_wastewater_using_natural_coagulants)

to natural coagulants. The sludge requires proper treatment and disposal. As natural coagulants showed very less sludge content and good removal efficiencies so they are capable of replacing synthetic coagulants.

Adsorption

Adsorption is the process of deposition of solid, liquid, gaseous and molecular species on the surface of adsorbent without undergoing any reaction. The use of any adsorbent whether it is natural (orange peel, banana peel) or synthetic (activated carbon, ion exchangers) etc. depends on factors like concentration of adsorbent, pH, dye adsorbent contact time

Natural adsorbents are nowadays also used for removing dye from effluent. The natural adsorbents are generally cheap waste material such as orange peel, banana peel, jackfruit seeds etc. These adsorbents have good colour removal efficiency and are economic as they are cheap and easily available.

Abdurrehman *et al.* 2013 [1] used orange peels as an adsorbent for removing dyes from effluent. Peels were washed, cut, dried and grinded by using a mortar. Different parameters

such as amount of adsorbent, pH, contact time between adsorb ate and adsorbent were optimized. The results showed that for removing dye from 25 ml of effluent 1.5 g of adsorbent dosage, contact time of 120 minutes and neutral pH was favorable.

Habib *et al.* (2007) [5] also used orange peel for removing copper from aqueous solution and they found that with the increase in adsorbent dosage the adsorption rate increases. This study showed that maximum adsorption of copper from aqueous solution by orange peel adsorbent is up to 1g/100ml.

Khaniabdi *et al.* (2017) [9] utilizes aloe vera leaves shells for preparing activated carbon which removed Congo red dye from effluent. Shells were dried, crushed and carbonized at 550^0C to prepare activated carbon. Activated carbon had maximum uptake for Congo red dye of 200mg/g initial dye concentration within 60 minutes.

Other natural adsorbents are natural clay, jackfruit seed, saw dust, sugarcane bagasse, banana peel, shrimp shell etc. They have varying optimum condition for each class of dyes and are advantageous economically because of their widespread availability.

Chemical Method of Dye Removal from Effluents

Chemical techniques conventionally involve the use of various reducing and oxidizing agents for removing dye from effluent. These techniques utilizes large amount of chemicals for dye removal. These chemicals have to be removed from water through other processes which add extra cost and sometimes are not efficient leading to improper separation of chemicals from water.

In chemical sustainable techniques reductive degradation of dyes takes place through silver nanoparticles are used because of their simplicity and high reaction rates. There are various ecofriendly materials such as vegetables, fruits, plant extracts, microbes, fungi which are used as precursors for synthesizing silver, carbon and other noble nanoparticles.

Edison *et al* (2016) [3] utilizes cashewnut testas for synthesizing silver nanoparticles Testas are the red skins covering the cashewnut. These skins were mechanically removed in confectionary. These testas were collected, cleaned, dried and grinded using mortar. Then 0.4 g of powder testa was mixed with 100ml distilled water and boiled at 90 ^{0} C for 20 minutes. Then 1ml of this prepared extract was added to 24 ml silver nitrate solution. Appearance of yellow colour indicates the formation of silver nanoparticles. Then 1ml of $NaBH_4$ (sodium borohydride) was also added which act as a reducing agent. The removal of methyl orange and Congo red dyes was done using the prepared solution. The results of the study revealed that methyl orange (2ml) took 15 minutes for complete decoloration whereas Congo red dye (2ml) took 20 minutes for complete decoloration.

Gannapuram *et al* (2015) also utilizes gold nanoparticles derived from salmalia malabarica (*Bombax ceiba*) gum for removing Congo red dye from effluent. Saika *et al* (2017) [15] removed Methylene blue, Congo red, Rhodamine B and Malachite green dye from effluent using gold and cerium oxide, titanium dioxide Nano composite (Au/CeO_2-TiO_2).

Biological Method of Dye Removal from Effluents

Biological techniques involve use of various bacteria, enzyme and fungi for degradation of dye molecules. Various bacterial cultures such as *Pseudomonas putida*, *Bacillus sp*., *Pseudomonas fluorescens*, *Geobacillus tearo thermophilus* etc. are used for removing dyes such as acid orange 10, azo dyes, Congo red, reactive orange, methyl orange, crystal violet etc. Karthik *et al*, (2014) [10] reported that *Pseudomonas fluroescens* and *Corynebac* showed 100 % removal of crystal violet dye at 50 ^{0}C within 58 hours whereas *Geobacillustea rothermophillus* show 96-98% removal of reactive azo orange dye within 24 hours only.

According to Joshi *et al.* (2004) [6], yeasts are also used for dye removal from effluent. *Klyveromyces marxianus* is an example of yeast which is used to remove colour from remazol black dye effluent.

Fungal cultures such as *Schizophyllum commune*, *Aspergillus allahbadii*, *A. sulphureus* shows good decolouration rate of synthetic dyes. The study of Karthik *et al* (2014) [10] reported that white rot fungus shows 100% decolouration rate of crystal violet and orange G dyes within 24 hours.

Mohan *et al.* (2012) [12] investigated the removal of direct red dye using fungal species *Aspergillus niger* and *Aspergillus flavus* at static and shaking conditions. The results of the study revealed that *Aspergillus niger* show about 100% removal of direct red dye at static conditions within 2 dyes whereas *Aspergillus flavus* showed 90% removal of direct red dyes within 2 days at shaking conditions.

Kalaiarasi *et al* (2012) [8] investigated different fungal species having higher percentage decolouration. The results showed that *Aspergillus* species have maximum decolouration rate.

In biological techniques of dye removal algae are also used for decolourising dye from effluent. Several species of algae such as spirogyra, chlorella, cosmarium, green algae, algal biomass, lyngbya etc are used for decolourising dye from textile effluent. According to Karthik *et al* (2014) [10], *cosmarium sp* of algae removes 92 % malachite green dye from textile effluent but it takes 24 hours.

Nigam *et al* (2016) [14] stated that use of algae in bioremediation of dye effluent is cost effective as well as require less energy because algae supplies oxygen to heterotrophic aerobic bacteria and increase the removal of pollutants from water such as dye, heavy metals etc.

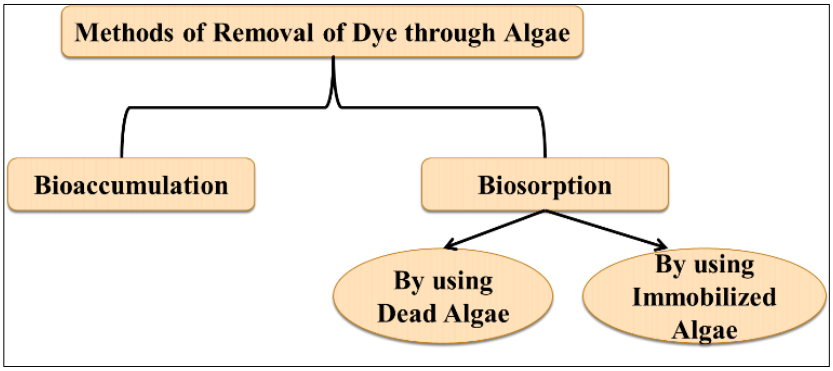


Fig 2: Methods of Dye Removal through Algae

Fig. 2 shows methods of dye removal through algae. The first method is known as bioaccumulation in which accumulation of dye takes place by living algae. It occurs mainly in two phases; rapid uptake in which dyes adsorb on the surface of algae and second phase in which algae slowly uptake the adsorbed dye molecule into its metabolic system after few hours of adsorption. Biosorption is done using dead and immobilized algae in which pollutants are bind and concentrated on the cellular structure. Kumar *et al.* (2014) [11] used dead algae like *Microspora sp*. and obtained 85% decolouration of methylene blue dye from effluent within 5 minutes under static conditions. Muzarabani *et al.* (2015) [13] reported that immobilized algae like *Desmodesmus sp* showed 98.6 % decolouration of methylene blue and malachite green dye within a period of 6 days. Karthik *et al.* (2014) [10] found that algal biomass decolourise 85% malachite green dye from textile effluent within 45 minutes only. Therefore algal species are useful for removal of dyes from effluent as compared to other biological sources like bacteria and fungi having high cost and low commercial production for large scale use.

Conclusion

Conventional techniques of dye removal from effluent such as physical, chemical etc. not only include high cost but also produces huge amount of sludge which require proper disposal treatment. These techniques concentrate the dye molecules and converted it into sludge and this sludge is disposed from the industries without any treatment and is responsible for causing pollution. So, to replace these conventional techniques which results in generation of huge amount of sludge, is to move towards the sustainable techniques which not only utilize cheap waste material for treating dye effluent but also produce little amount of sludge. And, also gives advantages such as low cost, high colour removal efficiency and reduced sludge production. From the above review it can be concluded that sustainable techniques are ecofriendly and do not cause any adverse impact on the environment and are very beneficial for the textile industries.

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