Ecofriendly Decolorization of Textile Wastewater using Natural Coagulants

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Abstract

The textile dyeing industry consumes large quantities of water and produces large volumes of wastewater from different processes in dyeing and finishing processes. The low-cost, easily available naturally prepared coagulants like moringa seed powder, maize seed powder, green bean powder and tamarind seed powder as an alternative to recent expensive coagulant methods for reactive dye removal has been investigated in this study. Various process parameters like pH, coagulant dose, flocculation time and also its optimization were exploited. The maximum percentage color removal was found to be 80.26, 78.30, 74.04, 72.68 and 70.53 for moringa, corn, aluminiumsulphate, green bean and tamarind, respectively, at pH 9.0, coagulant dose of 30 mgL^{-1}, flocculation time 120 min. The sludge volume index (SVI) was calculated for these parameters including process optimization. Natural coagulants were better coagulant than aluminiumsulphate which corresponds to color removal and sludge volume index.

Keywords : Coagulation, Natural coagulant, Reactive dye, Moringaoleifera, Drumstick, Zea mays L (corn), Green Bean, Tamarind

Introduction

The textile dyeing and finishing sector uses large volumes of water and substantial quantities of complex chemicals.The unused materials from the processes are discharged as wastewater that is high in color, biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), pH, temperature, turbidity and toxic chemicals[1]–[5]. Color is one of the most important environmental parameters. The dye's structures are high molecular weight and complex structures, resulting in greater difficulty to degrade the dyeing wastewater[6]–[9]. The discharge of textile wastewater to the environment may cause serious and very harmful to the environment if released without proper treatment[10], [11]. Hence, it becomes necessary to remove dyes from textile effluents before discharge to avoid negative environmental impacts.Adsorption, ion exchange, membrane filtration, coagulation and biological processes are the various treatment technologies for textile wastewater[12], [13]. Coagulation of dye-containing wastewater has been used for many years as main treatment or pretreatment due to its efficiency and low capital cost [14]–[18]. Many coagulants are widely used in conventional water treatment processes, based on their chemical characteristics. These coagulants are classified into inorganic, synthetic organic polymers, and natural coagulants. Aluminium sulfate (alum) is the most widely used coagulant in water treatment because of its proven performance, cost effectiveness, relative

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easy handling, and availability[19], [20]. However, some studies[21]–[25]have reported that aluminium which is the major component of alum may induced the Alzheimer's disease.Furthermore using aluminium salts as a coagulant produce a high volume sludge[26], reaction of aluminium with alkalinity present in the water that decrease the pH of water[27] and its low coagulating effect in cold water [28], [29]. Iron salts and polymeric compounds also are used as coagulant, but with limited effect and outcome. In general one of the main problems of these coagulants is production of high volume sludge that doesn't lose its water easily and causes problem [28], [30]. On the other hand, naturally occurring coagulants are biodegradable and are presumed safe for human health [20].Thus, in water treatment, the use of natural coagulants could be an option with many advantages over chemical agents, particularly the biodegradability, low toxicity, low residual sludge production and safe to human [31]. Recently, some natural polymers have been reported in literature to have the capability to treat the various types of wastewater[32]–[34]. Natural flocculants, mainly polysaccharides, are considered environmentally friendly in comparison with inorganic and organic coagulants. Recently, there has been a resurgence of interest in natural flocculants/coagulants for wastewater treatment in developing countries.In recent years, numerous studies on a variety of plant materials which can be used as source of natural coagulants have been reported. For example natural coagulants from Moringaoleifera (drumstick)[35], [36], tamarind seed [37], common bean (Phaseolus vulgaris) [38], Nirmali seed (Strychnospotatorum) [39] and mucuna seed [40] have been investigated.Color removal from textile wastewater using low cost and natural materials has been widely studied, but the use of water-soluble natural polymers has been scarcely reported. Natural polymers, mainly polysaccharides can be used as low cost adsorbents with many additional advantages such as ease of availability from renewable resources and biodegradability [20]. The aim of this work is to study the ability of moringa, maize, green bean and tamarind to remove reactive and disperse dye from aqueous solutions. The optimal flocculation conditions pH, coagulant dose and contact time were determined and to compare the efficiency between natural coagulant and chemical coagulant

Materials and Methods

1. Materials

The seeds were bought from a local super market (originally grown in Thailand). The aluminum sulphate [$Al_2(SO_4)_3 \cdot 18H_2O$] used in the present study was of laboratory grade. Reactive dyes; Drimarene brilliant blue CL-BR,Drimarene yellow CL-2RP, Drimarene red CL-58p were a gift from a local dye manufacture.

2. Preparation of dyeing synthetic wastewater

The characteristics of wastewater released from the dyeing process vary by the wastewater plant, sampling time and process conditions. Therefore it was required to prepare synthetic wastewaters with average concentrations of additives in for the testing samples[41]. Synthetic reactive dye wastewaters were prepared by mimicking operating conditions of the dyeing process.The reactive dye was first dissolved in water, containing NaCl, $Na_2CO_3$and NaOH to obtain an alkaline solution with 100 mgL^{-1}dye concentration. Then, synthetic dye wastewaters were prepared by 1 h solution hydrolysis at 50 °C.

3. Preparation of natural coagulants seed powder

The whole seeds of moringa, maize, green bean and tamarind were ground to fine powder using a laboratory mill and sieved through 0.4 mm sieve. The fraction with particle size less than 0.4 mm was used in each experiment.

4. Extraction of active component from seed

The active component from coagulant was extracted using sodium chloride (NaCl). Ten grams of seed powder was suspended in 1 L of NaCl water solution (0.5 mol/L). The suspension was stirred using a magnetic stirrer for 10 min to extract active coagulation component. The solution was then filtered using Whatman no. 42 filter paper. The resultant filtrate solution was used as a coagulant. In order to prevent any aging effects, such as change in pH, viscosity and coagulation activity due to microbial decomposition of organic compounds during storage a fresh solution was prepared for each sequence of experiments [42].

5. Coagulation experiments

Coagulation studies were conducted in triplicate using jar test. The synthetic wastewater (250mL) was filled into the beakers (500mL). Add varying doses of seed extracts i.e. from 10 mgL^{-1} to 50 mgL^{-1} to each beaker and mixed for 1 minutes at 100 rpm for rapid mixing followed by 25 minutes slow mixing of 30 rpm. All the suspensions were then left for sedimentation; after 1 h of sedimentation, upper clarified liquid was collected from the top of the beaker and measured the percentage of color removal using UV-VIS spectrophotometer. Color removal removal corresponding to various does of seed extracts ranging from 10 to 50 mgL^{-1} were measured and the least dose producing maximum removal was designated as optimum coagulant dose. Optimum system pH was found by adding the optimum coagulant dose and the sample was varied from 5.0-9.0 and the pH value producing maximum color removal (optimum pH) was determined. The coagulation experiments with alum were performed only for comparison purposes. Coagulation efficiency was calculated as:% removal = $[(C_o-C_e)/C_o] \times 100$

where C_o and C_e (mg L^{-1}) are the concentrations of dye before and after adsorption

6. Analytical methods

All analytical methods followed the Standard Methods[21].Turbidity was measured using a turbidity meter (Eutech NT-100) and it was expressed in nephelometric turbidity units (NTU). The pH measurements were made on a digital pH meter (CyberScans PC 200). Apparent color was measured using UV-VIS spectrophotometer (Thermo Helios Aquamate). The coagulation experiments were conducted using Jar test (Stuart Scientific SW1)

Results and Discussions

1. Performance of selected plant extracts.

In this study the coagulation-flocculation test was carried out with aqueous solutions of three shades of synthetic reactive dyes: Drimarene brilliant blue CL-BR, Drimarene yellow CL-2RP, and drimarene red CL-58p. The table 1 shows detail of the dyes (100 mgL^{-1}) and Fig. 1 shows the effect of treating reactive wastewater samples with four difference seeds extract and aluminum sulphate by using 30 mgL^{-1} concentration. To remove color from dye wastewater, moringa produced the best results with an average percentage in color removal is 80.26%

Table 1 Details of the dyes (100 mgL^{-1})

Dye shade	pH	turbidity (NTU)	COD (mg/l)	λmax (nm)	Absorbance
blue	9.91	92.8	1515.4	598	0.530
yellow	11.68	18.97	1581.0	425.5	2.160
red	10.33	45.2	1294.5	540	1.885

Figure 1 The effect of treating reactive wastewater with coagulants.

Natural seed extracts have been found to act as coagulant because of their polyelectrolytes. In wastewater it act as polyvalent ions, this polymer chain carries a very large numbers of ionic sites along its length. Polymer from seed extracts takes place by the neutralization of charges on the electronegative colloids particles in wastewater.It was reported that extracts of Moringa as a soluble protein that have a positive charge (cationic peptides) It can reduces the amount of suspended solids in the water. [20], [23], [43], [44]. Including the proteins extracts from bean and corn, have coagulant properties which reduce the turbidity of the water. From the literature review Most reported that Moringa seed extract is a substance that has the potential to reduce the turbidity of the water. Main mechanism of coagulation with moringa seed was adsorption and charge neutralization. The Moringa seed extract is cationic peptides. It can adsorbed by colloidal particles with opposite charges and can make the electric potential of the colloidal particles decreased [19], [23] It reduces the negative charge of suspended particles in the water. Suspended particles are larger, as well as floc which can be precipitated and separated from the water by sedimentation or filtration [27]. The mechanism of reducing suspended solids in water using a protein extracted from Moringaoleifera seeds is similar to the synthetic polymer.

2. Effect of coagulant dose on percent dye removal

Coagulation dosage is one of the most important factors that have been considered to determine the optimum condition for the performance of coagulants in coagulation and flocculation. Essentially, insufficient dosage or overdosing would result in the poor performance in flocculation. The effect of coagulant doses, 10 to 50 mgL^{-1} for the removal of color from reactive dye wastewater using moringa, corn, green bean and tamarind was shown in (Figure 2).

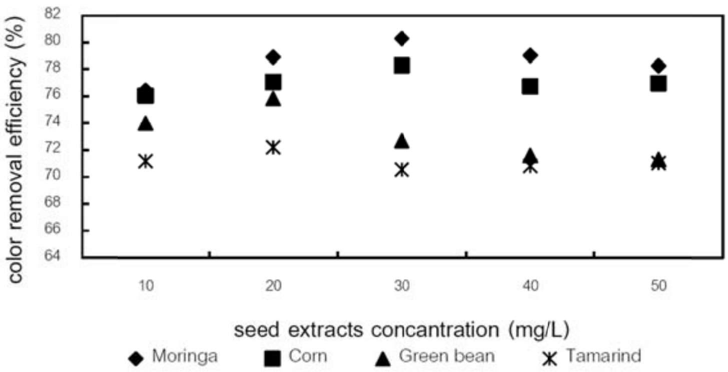


Figure 2 Effect of coagulant dose on the color removal.

The results of batch test for each natural coagulant are presented in (Figure 2). It was found that the removal rate increased with an increase in dosage initially and then followed by a decreasing trend in dye removal with further increase in dose level. The most effective dose of seed extracts was found to be 20 mgL^{-1} for Green bean and Tamarind, 30 mgL^{-1} for Moringa and corn, respectively, at which the maximum dye removal was observed. This trend (increasing and then decreasing trend) in percent of color removal was because of the fact that the optimum amount of seed extracts caused larger amounts of dye particles to aggregate and settle. However, an over optimum amount of coagulant in dye solution would cause the aggregated particle to redisperse and would also disturb particle settling [45].

3. Effect of pH on percent dye removal

pH is an important role in the coagulation process [46], [47]. Coagulant chemicals have an optimum pH range in which good coagulation and flocculation occur in the shortest time with a given dosage. The type of colloid in the water also affects the pH range for efficient coagulation. The effect of pH was one of the parameters was crucial to determine the optimum level in order to minimize the dosing cost and obtain the optimum performance in treatment. The aqueous solution of dyes having concentration of 100 mgL^{-1} were treated by constant concentration of 30 mgL^{-1} of seed extract with varying pH 5-9. pH variation in comparison had a significant effect on the decolorization of reactive dye by seed extract.

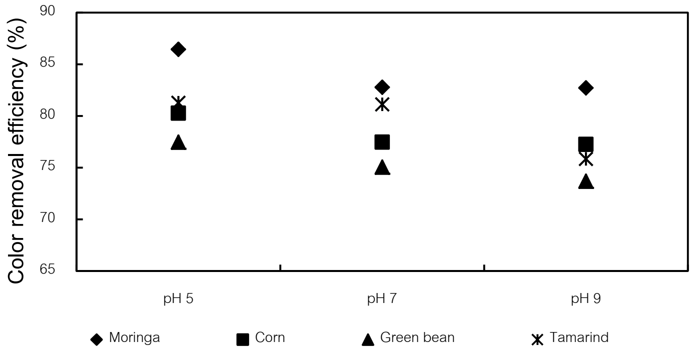


Figure 3 Effect of various pH on decolorization-reactive dye by seed extract.

(Figure 3) shows that the highest color removal was detected in pH 5. The removals of dyes are more at lower pH, because the plant extract containing protein and have positively charged. It works well at low pH[48]. However, seed extract from moringa, green bean, corn and tamarind can be used as natural coagulant with in the pH range 5-9.

4. Effect of Dye types

Comparative efficiency of color removal between reactive and disperse dyes and follows a different shade of blue red and yellow with seed extracts. The experimental results shown in Fig. 4

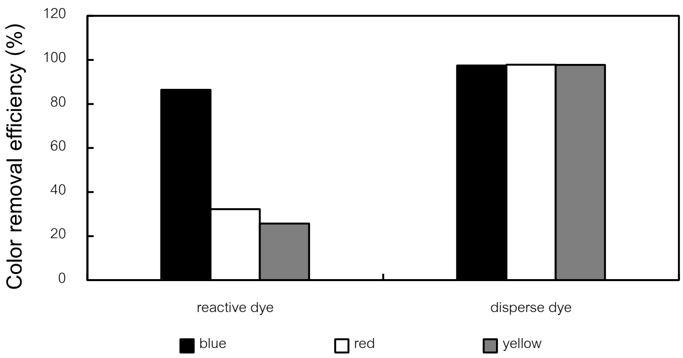
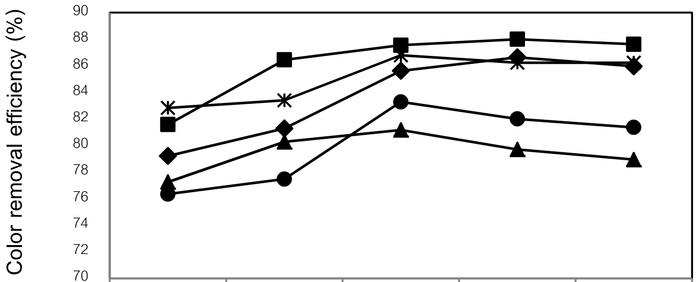


Figure 4 Types of dyes on color removal with natural coagulant.

The test statistics with the t test showed that the types of dyes affects color removal with natural coagulant from seed extract. The color removal of reactive dye is efficiency less than disperse dye. Because the reactive dyes are a color that can be water dissolved due to the negative charge of the sulfonate group (SO_3^-) and disperse dyes are water insoluble dyes. The color shade affect the efficiency of reactive color removal natural coagulant. The color removal of reactive dye the result found that blue is more easily eliminated than red and yellow. On the other hand for the disperse dye, the color shade does not affect the efficiency of disperse color removal.

5. Effect of coagulation time on percent dye removal

The flocculation time is one of the operating parameters that is given great consideration in any water treatment plant that involves coagulation–flocculation operations. (Figure 5) represents the effect of flocculation time for removal of color using coagulants i.e. moringa, corn, green bean, tamarind and alum. (at theirs optimum condition)



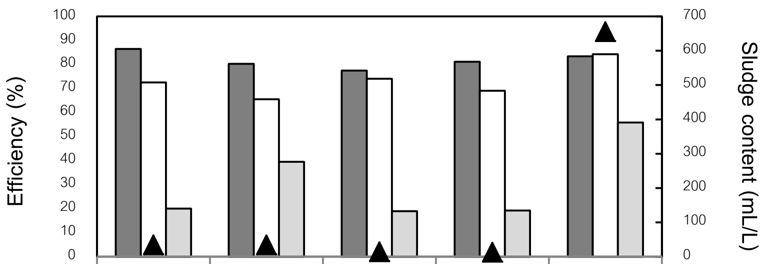
	30	60	90	120	150
Moringa (30mg/L)	81.58	86.45	87.55	88	87.62
Corn (30mg/L)	77.25	80.27	81.17	79.7	78.94
Green bean (20mg/L)	76.34	77.47	83.28	82	81.36
Tammarind (20mg/L)	79.21	81.28	85.62	86.64	85.96
Alum (210mg/L)	82.83	83.4	86.79	86.23	86.23

Figure 5 Effect of flocculation time for removal of color from reactive wastewater

The amount of dye removed increased up to the optimum contact time and then became constant. The maximum removal of the dyes by each seed extract was found to be after 1.30 h. After this time percent removal was nearly constant.

6. The performance of wastewater treatment between each seed extracts and alum

Compare the performance of wastewater treatment between each seed extract and alum in the optimum condition of each coagulants. The experiment results shown in (Figure 6)



	Moringa (30mg/L)	Corn (30mg/L)	Green bean (20mg/L)	Tamarind (20mg/L)	Alum (210 mg/L)
■ 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/L)	34.56	34.56	14.4	12.8	655.36

Figure 6 Compare the performance of wastewater treatment between each seed extract and alum

The results showed that each coagulant has different optimal conditions for wastewater treatment. At it's optimum conditions; moringa seed extract has maximum on color removal, followed by aluminum sulfate, tamarind, corn and green beans. The percentage color removal were86.45, 83.43, 81.28, 80.27 and 77.47 respectively.

The highest removal of color and COD was found to be 86.45 and 39.52% respectively using moringa. Further, highest removal of turbidity was found to be 74.26% using aluminiumsulphate. Seed extracts generate lower sludge volumes in comparison with aluminium[43], [49].

Conclusion

It is important to develop a bio-degradable and eco-friendly organic coagulant without secondary pollution for wastewater treatment. Seeds of molinga corn green bean and tammarind contain materials that are effective as coagulant. Coagulant dose and coagulation pH are important factors influencing the mechanism of coagulation. Also the type and chemical structure of the dyes plays an important role in the coagulation process. These alternative natural coagulants have several advantages compared to alum. The sludge volume is much lower than that produced with alum and the natural alkalinity is not consumed during the treatment process.

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