*J. Mater. Environ. Sci. 6 (6) (2015) 1672-1677*
*ISSN : 2028-2508*
*CODEN: JMESCN*


# Efficacy of *Moringa oleifera* and*Phaseolus vulgaris* (common bean) as coagulants for the removal of Congo red dye from aqueous solution

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**Abstract**
The efficiency of *Moringa oleifera* and *Phaseolus vulgaris* (common bean) as coagulants for the removal of Congo red dye from aqueous solution was studied. Batch experiments were carried out to study the effect of various process parameters such as pH, coagulant dose, initial dye concentration and settling time on dye removal capacity of the coagulant and the optimum condition for maximum dye removal was identified. Maximum percentage dye removal of 83% and 73% was achieved at pH 4 with an initial concentration of 50 mg/L for *Moringa oleifera* and *Phaseolus vulgaris*, respectively. The results obtained by using natural coagulants (*Moringa oleifera* and *Phaseolus vulgaris*) were compared with the results of commercially used coagulant 'Alum'. It is inferred from the study that the *Moringa oleifera* and *Phaseolus vulgaris*are efficient in removal of Congo red dye from aqueous solution.

*Keywords*:*Moringa oleifera*, Common bean, Coagulation, Congo red.

## 1. Introduction

Textile industry wastewater consista large variety of dyes and chemicals which alter the effluent quality in a wide range and the main concern is not only the chemical composition of liquid waste but also the dyes and pigments present in it [1]. The dyeing and finishing processes in the textile industry are the main source of pollution and the removalof colour from wastewater generated from these processes is a major environmental concern[2].The effluent generated fromvarious manufacturing processes of a textile industry has a high pH, temperature, detergents, oil, suspended and dissolved solids, dispersants, levelling agents, toxic and non-biodegradable matter, colourand alkalinity [3].The most commonly used methods for removing colour fromthe textileindustry wastewater involve physical and/or chemical processes and are summarised in Table 1 [4]. These methods are often very costly and, although the dyes are removed, accumulation of concentrated sludge creates a disposal problem.Generally the coagulants used in the conventional methods are lime $Ca(OH)_2$, aluminium salts $Al_2 (SO_4)_3$ and $AlCl_3$) and iron salts ($FeCl_3$ and $Fe_2 (SO_4)_3$) [5]. Due to these chemicals, there is a possibility that a secondary pollution problem will arise because of excessive chemical use in the treatment.Because of the adverse effect of textile wastes in environment, many industries were forced to close their activities [6] [7]. Colour removal is one of the most important steps in wastewater treatment process, which is generally achieved using coagulation process using suitable coagulants. Among the methods for colour removal (Table 1), it is evident that coagulation is the economical process, but it produces large quantity of sludge.

**Table 1**. Current treatment technologies for colour removal involving Physical and/or chemical processes

| Physical and/or chemical methods | Advantages | Disadvantages |
|---|---|---|
| Oxidation | Rapid process | High energy costs and formation of by-products |
| Adsorption | Good removal of a wide range of dyes | Absorbent requires regeneration or disposal |
| Membrane technologies | Removes all dye types | Concentrated sludge production |
| Coagulation/flocculation | Economically feasible | High sludge production |

Natural plant extracts have been used for water purification for many centuries. Most of these extracts are derived from the seeds,leaves, pieces of bark or sap, roots and fruit extracts of trees and plants. Natural coagulants have been reported to have several other advantages compared to commonly use synthetic coagulants such as alum, ferrous sulfate, ferric chlorosulfate and ferric chloride [8].A comparison of natural coagulants over conventional chemical coagulants is presented in Table 2. It wasreported that the sludge produced from *Moringa oleifera*coagulated turbid water is only 20–30% that of alum [9] and*Phaseolus vulgaris*(common bean) seeds were also used as coagulant which has the coagulation efficiency of more than 40% [10].Also, it has been reported that the residue of alum in water may be carcinogenic [11-13]. Natural coagulants are biodegradable and cost effective, and also have a wider effective dosage range for flocculation of various colloidal suspensions [14].

**Table 2.** Advantages of natural coagulants over conventional chemical coagulants

| Parameters | Natural Coagulants | Conventional Chemical Coagulants |
|---|---|---|
| **Cost** | Sustainable and economical | Complex and expensive |
| **Toxicity** | Nontoxic to environment | Highly toxic |
| **Corrosiveness** | Noncorrosive to the materials | Highly corrosive due to alkalinity |
| **Sludge Characteristics** | Small amount of non-hazardous & biodegradable sludge | Large amount of hazardous & non-biodegradable sludge |
| **pH** | Do not alter the pH of water under treatment. | More changes in pH due to metallic salts |
| **Sensitiveness** | Provides rapid flocculation and decantation | Provides slow flocculation and decantation |
| **Fragrance** | Acts as a deodorant agent forming insoluble complexes with organic species such as proteins and carbohydrates. | Offensive odor due to decomposed chemicals in the sludge |

Although, researchers have studied the effectiveness of natural coagulants for colour removal, the detailed literature review reveal that no study has been conducted on removal of Congo red dye (using *Moringa oleifera* and*Phaseolus vulgaris)* and hence, in the present work, an attempt has been made to investigate the effect of natural coagulants *Moringa oleifera* and*Phaseolus vulgaris* on the removal of Congo red dye from aqueous solution. The efficiency of these natural coagulants compared to the conventional chemical coagulants like Alum is highlighted.

## 2. Materials and methods

*2.1 Preparation of synthetic dye solution*

Congo red (Figure 1) is an anionic azo dye and is the sodium salt of benzidinediazo-bis-1-naphthylamine-4-sulfonic acid.Table 3 shows the physicochemical properties of the Congo Red Dye. 1g of Congo red dye was dissolved in 1L of double distilled water to obtain stock solution. Later, it was diluted by using distilled water to get the desired concentration and pH was adjusted by adding 0.1 M NaOH and 0.1 M HCl.

**Table 3**.Physicochemical properties of the Congo reddye.[15]

| Parameter | Values |
|---|---|
| **Molecular weight** | 696.66 g/mol |
| **Molecular formula** | $C_{32}H_{22}N_6Na_2O_6S_2$ |
| **Absorption maxima** | 490 nm |
| **Color** | brownish-red powder |
| **Dye class** | Azo |
| **Odor** | Odorless |
| **Solubility** | Soluble in ethanol&acetone; practically insoluble in ether |
| **pH** | Solution have pH of 8-9.5 |
| **pKa** | 4.1; 3.0 |
| **Toxicity** | May cause cancer |

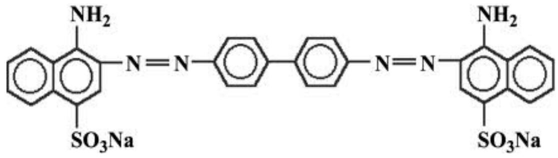

**Figure.1** Molecular Structure of Congo red.

*2.2 Preparation of natural coagulant*

*2 .2.1 Moringa oleiferaseeds*

The husk covering the dried seeds of *Moringa oleifera* were removed and dehulled manually. The kernels were crushed to powder using an ordinary mixer grinder and sieved through 200 µm nylon sieves to make use of it as coagulants[16].

*2.2.3 Phaseolus vulgarisseeds*

*Phaseolus vulgaris* (Common bean) seeds were collected and dried at 65°C for 24 hours in hot air oven. The dried seeds were crushed using ordinary mixer grinderand passed through a sieve with pore size of 400 µm.10 g/L of the smaller fraction was suspended in 0.5 mol/L NaCl and stirred for 10 minutes on a magnetic stirrer in order to extract active coagulant. After which, the suspension was filtered through Whatmanno. 42 filter paper and the obtained filtrate, called crude extract, was stored in a refrigerator at 4ºCfor further use [10].

*2.3 Experimental procedure*

The coagulation studies were performed using Jar test apparatus. The beakers were filled with 1000ml dye sample and the coagulant dose of 10-50 mg/L (for *Moringa oleifera*and Alum) and 10-50 mL/L (for *Phaseolus vulgaris*)was added. A rapid mixing at 100 rpm for 2 minutes was carried out followed by slow mixing at 40 rpm for 30minutes. Later the dye samples in the beakers were allowed for settling for 30 minutes. The supernatant after sedimentation was filtered using Whatman no. 42 filter paper and the filtrate was analyzed for absorbance using UV spectrophotometer at a maximum wavelength 475 nm. Color removal efficiency was measured as a decrease in optical density measurement at 475 nm. The percentage colour removal was calculated using following equation (1):

$$\frac{C_i - C_f}{C_i} \times 100 \qquad (1)$$

Where, $C_i$and$C_f$ are the initial and final concentration of dye solution, respectively.

## 3. Results and discussion

*3.1 Effect of pH*

In the coagulation process, the factor of pH affects the surface charge of coagulants and also the stabilization of the suspension. Figure 2 depicts the effect of pH on the removal of Congo red dye with initial concentrations of 50, 100, 150 and 200 mg/L using *Moringa oleifera*(Fig. 2a),*Phaseolus vulgaris* (Fig. 2b) and Alum (Fig. 2c). The experiments were conducted using coagulant dose of 30 mg/L.It can be noted from the figure that the maximum colour removal was achieved at pH 4 for all the coagulants studied. For*Moringa oleifera*, the amino groups are protonated in acidic solution which makes it positively charged and act as a cationic polyelectrolyte[17]. As the particles in dye are negatively charged, natural coagulant was very attractive by allowing the molecule to bind to the negatively charged surface via an ionic or hydrogen bonding which will further reduce or neutralize the particles surface charge [18]. Hence, the particle destabilization by coagulants could be explained by charge neutralization mechanism [19].

*3.2. Effect of coagulant dosage*

Coagulation dosage is one of the most important parameters 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. Hence, it is significant to determine the optimum dosage in order to minimize the cost of coagulant dose and sludge formation and also to obtain the optimum performance in treatment. The effect of coagulant dose on colour removal using *Moringa oleifera* (Fig. 3a), *Phaseolus vulgaris* (Fig. 3b) and Alum (Fig. 3c) was studied by maintaining pH 4, temperature of 27°C and settling time 45 minutes and the results are presented in Figure 3.It can be noted from the figure that the percentage colour removal increases with increase in coagulant dose and the maximum colour removal was achieved at the coagulant dose of 30 mg/L for *Moringa oleifera* and Alum and 30 mL/L for *Phaseolus vulgaris*. Further, it can be noted that the maximum percentage removal of colour was found to be 83%, 73% and 77% for *Moringa oleifera*, *Phaseolus vulgaris* and Alum, respectively.

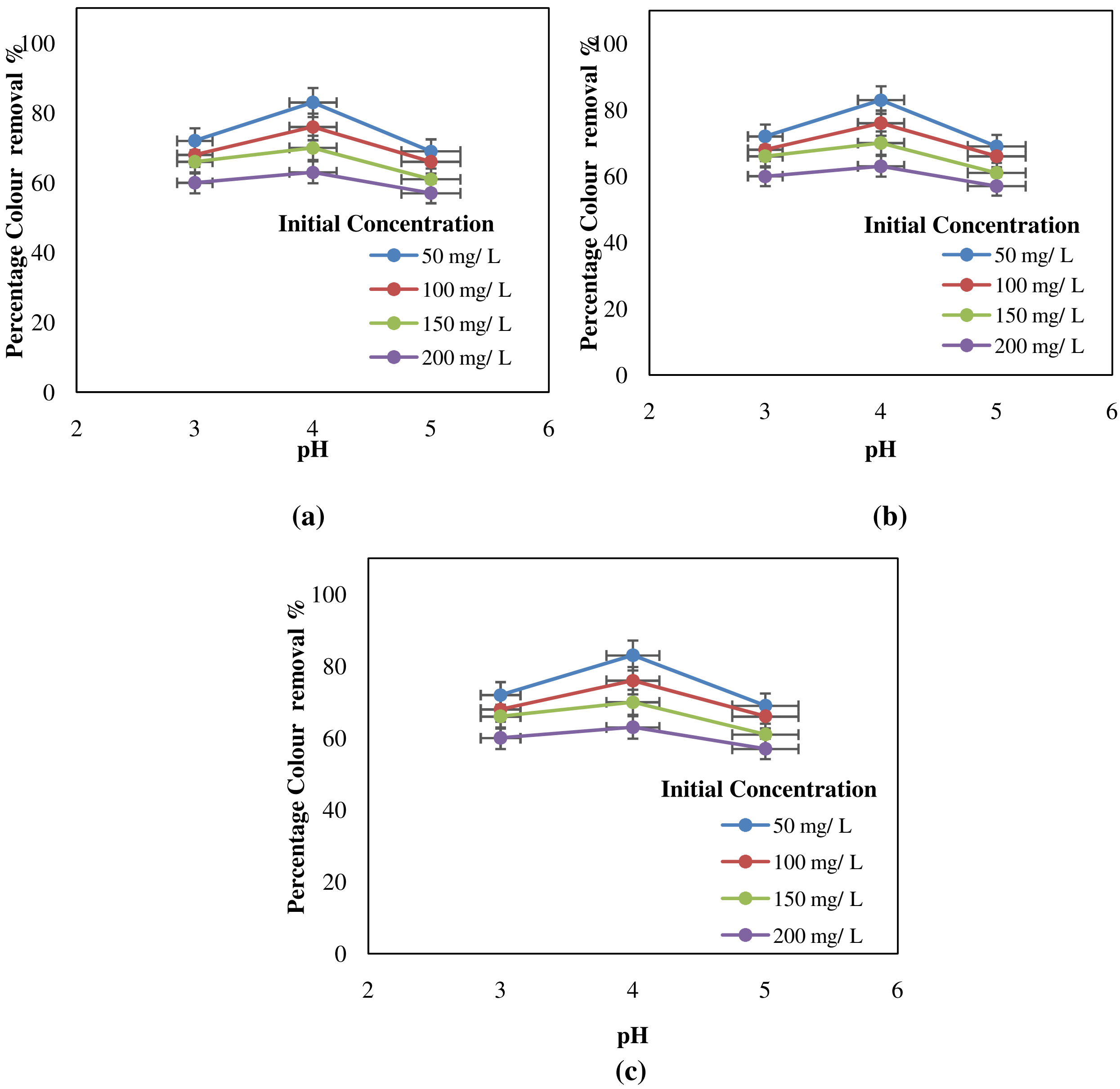


**Figure 2.** Effect of pH on colour removal using (a)*Moringa oleifera,* (b) *Phaseolus vulgaris*and(c)Alum

*3.3 Effect of settling time*

The settling time is one of the operating parameters that are given great consideration in any water/wastewater treatment plant that involves coagulation operations. Figure 4 depicts the effect of settling time on colour removal using different coagulants. It can be observed from the figure that there is a consistent increase in colour removal with increase in settling time. The optimum settling time was found to be 60 minutes for the natural coagulants *Moringa oleifera*and *Phaseolus vulgaris*and 50 minutes for the conventional commercial coagulant Alum. It is evident that increase in settling time increases the percentage of colour removal. The optimum condition for maximum removal of Congo red dye is presented in Table 4.

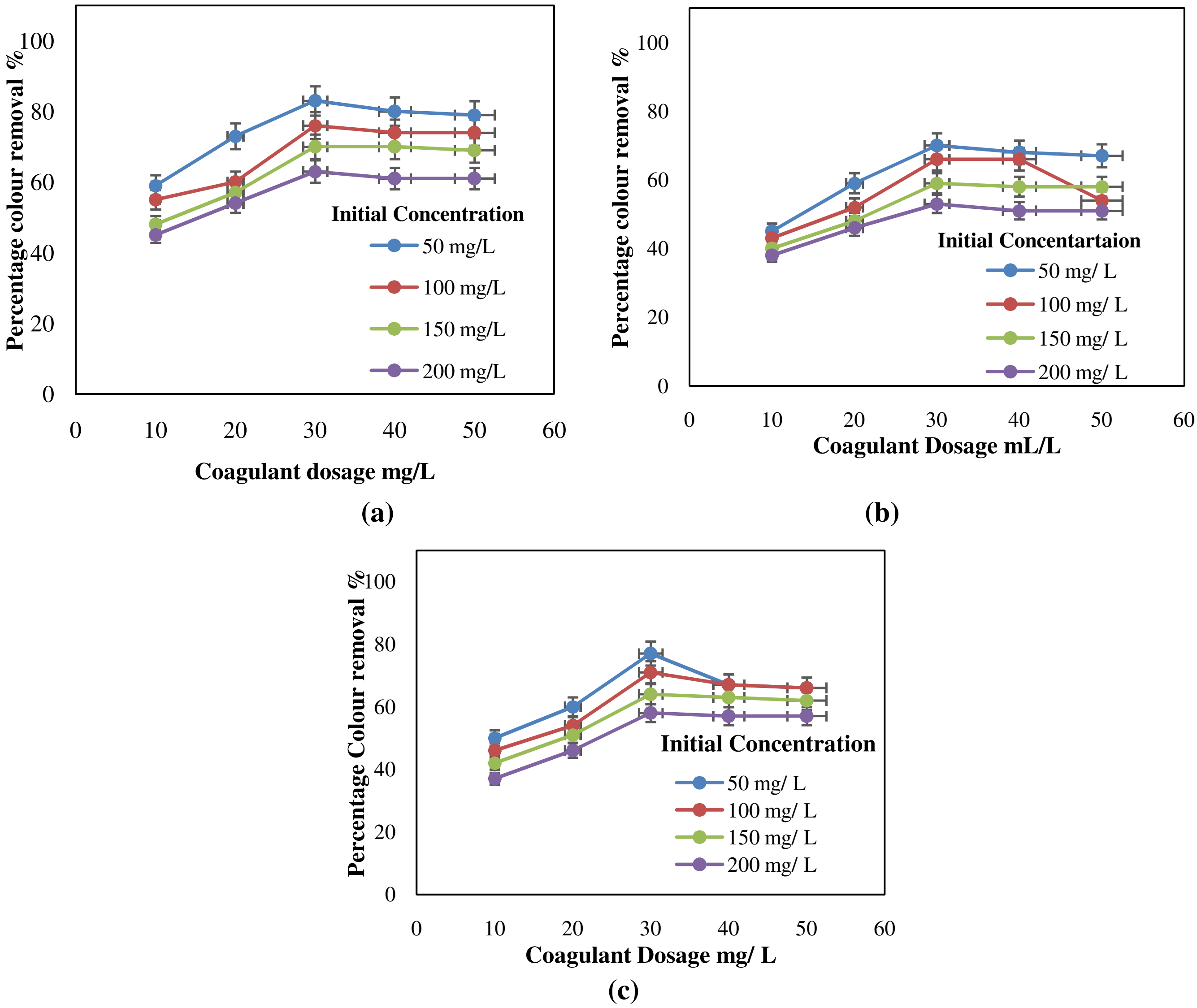


**Figure 3.** Effect of coagulant dosage on colour removal using (a) *Moringa oleifera,* (b) *Phaseolus vulgaris*and (c) Alum

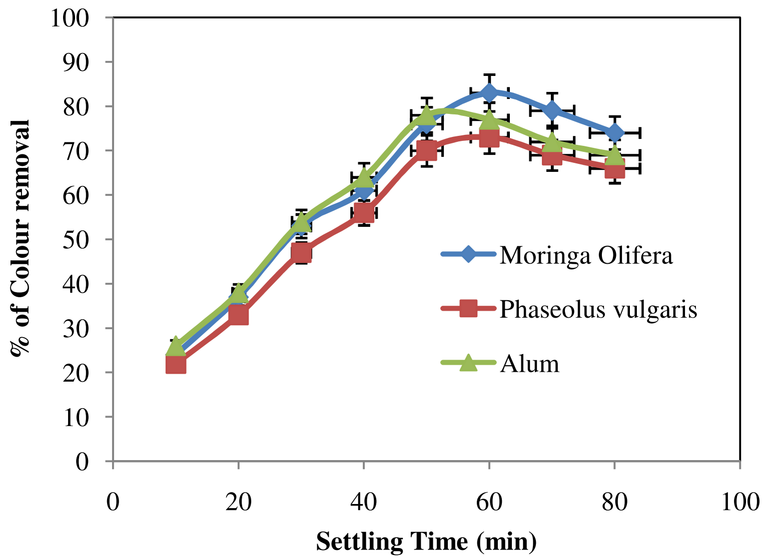


**Figure 4.** Effect of settling time on colour removal

**Table 4.** Optimum condition for Congo red dye removal at pH 4

| Coagulant | Initial dye concentration $C_i$ (mg/L) | Coagulant dose | Settling Time (min) | % Dye removal |
|---|---|---|---|---|
| *Moringa oleifera* | 50 | 30(mg/L) | 50 | 83 |
| *Phaseolus vulgaris* | 50 | 30 (mL/L) | 50 | 73 |
| Alum | 50 | 30(mg/L) | 60 | 77 |

## Conclusion

The natural coagulants *Moringa oleifera* and *Phaseolus vulgaris* were studied for its efficiency in removal of Congo red dye from aqueous solution by considering the influencing parameters such as pH, coagulant dose, initial dye concentration and settling time. The optimum condition for maximum colour removal wasachieved as: pH 4, coagulant dose of 30 mg/L for *Moringa oleifera* and Alum and 30 mL/L for *Phaseolus vulgaris.* The optimum settling time was identified as 60 minutes for the natural coagulants *Moringa oleifera* and *Phaseolus vulgaris* and 50 minutes for the conventional commercial coagulant Alum. The maximum percentage removal of colour was found to be 83%, 73% and 77% for *Moringa oleifera*, *Phaseolus vulgaris* and Alum, respectively. It is evident from the results that the natural coagulants *Moringa oleifera* and *Phaseolus vulgaris* are equally efficient in removal of Congo red dye from aqueous solution compare to the conventional commercial coagulant Alum.

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