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Assessing the Performance of Bio-Coagulant and Traditional Alum Coagulants in Surface Water Treatment Process

M.S. Alam[1], S. M. I. Islam[2]

[1]Bangladesh Bridge Authority, Bangladesh (shakhawathalam13@gmail.com)
[2]Department of Civil Engineering, The University of Texas Rio Grande Valley, Texas, USA (skmdimdadul.islam01@utrgv.edu)

Abstract

This study focused on the evaluation of plant-based natural coagulant sources, processes, effectiveness and relevant coagulating mechanisms for the treatment of surface water. This study selected Sajna (M. oleifera) and Neem (A. indica) seeds as bio coagulants. The optimum dose for the Sajna and Neem seeds coagulant was found as 32 mg/l and 40 mg/l respectively, for the selected river water. It is found that the turbidity removal efficiencies of the coagulants are varied from 94.5 to 96.5 % with compared to alum coagulation. Turbidity removal efficiency of Sajna seeds is found approximately 1.7% higher than Neem seeds. The color removal efficiencies of the coagulants are varied from 83.6 to 87.1% with compared to alum coagulation. Color removal efficiency of Neem seeds coagulant is found approximately 3.5% higher than Sajna seeds. However, it is also observed from the linear correlation that the turbidity and color removal efficiency decrease with the initial values of raw water samples. The main advantages of using natural plant-based coagulants are apparent; cost-effective, abundant source, environment friendly, multifunction and unlikely to produce treated water with extreme pH and highly bio-degradable. The use of bio-coagulant would be a possible alternative to chemical coagulants for the treatment of surface water in rural areas and developing countries like Bangladesh.

Keywords: *Bio-coagulant; Alum coagulants; Turbidity removal; Color Removal; Biological Water treatment*

1 Introduction

In many developing counties, access to clean and safe water is a crucial issue. Developing counties pay a high cost to import chemicals for water treatment. Various methods are used to make water safe, and the method employed depends on the character of the raw water. One of the problems with the treatment of surface water is large seasonal variation of turbidity. Chemical coagulation is one of the most popular and effective methods for suspended particle and turbidity removal. Several categories of chemical coagulants are used in water treatment, such as ferric series, aluminum series, lime, organic polymer, polyelectrolyte, etc. However, these reagents may exert a negative impact on health as applied to drinking water treatment because they leave harmful monomers, aluminum, and unwanted side products in effluent, especially for excessive usage (Srinivasan and Viraraghavan, 2002). It has been found that turbidity removal efficiencies of the coagulants are varied from 86.3 to 96% compared to alum coagulation and It is also found that the turbidity and color removal efficiencies (>70%) are satisfactory for the coagulant which is significant for use as a coagulant in water treatment purpose (alam & Islam, 2020). The aluminum residue in drinking water, always changes with the dosage of chemical coagulant and may exceed the values under an excessive usage conditions. Uncontrolled uses of Alum in water treatment process may be ended up to the waterbody and may also have a significant impact in marine environment (Islam, Islam, Raihan, & Hossain, 2019). Since bio-coagulant is made of natural material, it is biodegradable and possesses a high ecological affinity. No harmful contaminants will be left in water effluent and the final sludge after bio-coagulant application, therefore the environmental risks resulting from water utilization and sludge dumping can be avoided completely. Natural coagulants, mainly polysaccharides and proteins, are considered eco-friendly compared to inorganic and organic coagulants because of their biodegradability (Antov et al., 2010). These bio-coagulants can be a cheaper source for poor people who needs safer and healthier water source for the domestic uses in the slum (Islam & Das, 2018). Besides having these natural coagulants, now-a days, Nanotechnologies are playing a vital role in the wastewater treatment. However, Nanotechnology application requires proper training, knowledge and systematic approach which significantly lack in developing and underdeveloped countries (Acharya, Alam, & Islam, 2022) (alam & Islam, 2020). For this reason, natural

coagulants have bright future and are concern by many researchers because of their abundant source, low price, environment-friendly, multifunction, and biodegradable nature in water purification. Moringa oleifera extract has been found as a promising material as well as an environmental-friendly and low-cost to treat surface water treatment (Nhut, et al., 2020). These natural coagulants can also be used in the ETP after doing some of the parametric test of the water in big scale in future as finding an ETP with above 96% efficiency in Bangladesh is difficult because of having many mismanagement and operational issues (Islam, Hossain, & Raihan, 2020).

2 Objectives of the study

The main objectives of the study are given as follow:

- To choose suitable bio-coagulants for the treatment of surface water for drinking purpose.
- To study the turbidity and color removal capacity of the selected bio-coagulants.
- To check the efficiency of the bio-coagulants with respect to traditional alum (K_2 $[SO_4].Al_2$ $[SO_4]_3.24H_2O$) coagulation.

3 Methodology

- Collection of raw water samples from the Bhairab River.
- Selection of suitable bio-coagulants.
- Preparation of bio-coagulants.
- Determination of water quality parameters (turbidity, color, pH and conductivity) of the collected sample.
- Performing of Jar test (coagulation) for both seeds for both river water and pond water sample.
- Determination of optimum dose for the turbidity and color removal capacity for the selected bio-coagulants.
- Analyzing the test results and plotting relevant graphs.
- Analyze and compare the efficiency of Sajna and Neem seeds as bio coagulants with respect to traditional chemical alum coagulant.

3.1 Selection of Coagulants

There are different types of naturally available bio-coagulant like Sajna or Drumstick Seed (*Moringa oleifera)*, Neem seed (*Azadirachta indica*) organic PAC (Polyaluminium chloride), *Acanthocereus tetragonus*, Aloevera leaf, Chitosan, Anionic polymer, Cationic polymer, Non-ionic polymer, *Cicer Arietinum*, *Delonix regia*, *Dolichos Lablab*, PG-M (hybride type), *S.potatorum* (seeds of nirmali trees), guar plant (*Cyamopsis tetragonoloba*), tamarind tree (*Tamerindous indica*), and *Ipomoea dasysperma* seed gum, as coagulants. *Moringa oleifera* or locally named Sajna seeds and *Azadirachta indica* or locally named Neem seeds were selected as bio-coagulant due to their availability in Khulna district and cost effective. Alum is selected as chemical coagulant. It is a common coagulant available in local market and cheaper than other chemical coagulants.

3.2 Collection of Raw Water and Preparation of Bio-Coagulants

The raw water samples were collected from the Bhairab River ($22^0$53’56.4” N $89^0$31’06.8” E) located at Fulbarigate of Khulna within the month of February to April in 2022 in different time of the day with an average temperature of 28.5^0 C. Raw water was collected from different locations of the sources to maintain varying turbidity. The collected seeds were vigorously washed thoroughly tap water. The seeds were naturally sun dried for 2-3 days. Then the outer cover the seed kernels were removed, and the kernels were converted into powder using a blender. The prepared powders were used for each batch run.

Table 1. Indicated doses for each coagulant.

Coagulant	Indicated doses for each coagulant (mg/l)					
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Sajna	0	8	16	24	32	40
Neem	0	10	20	30	40	50

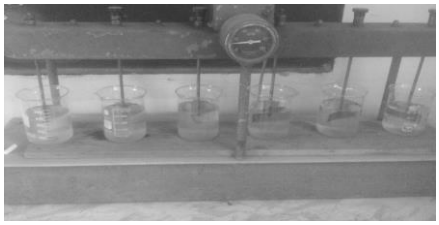


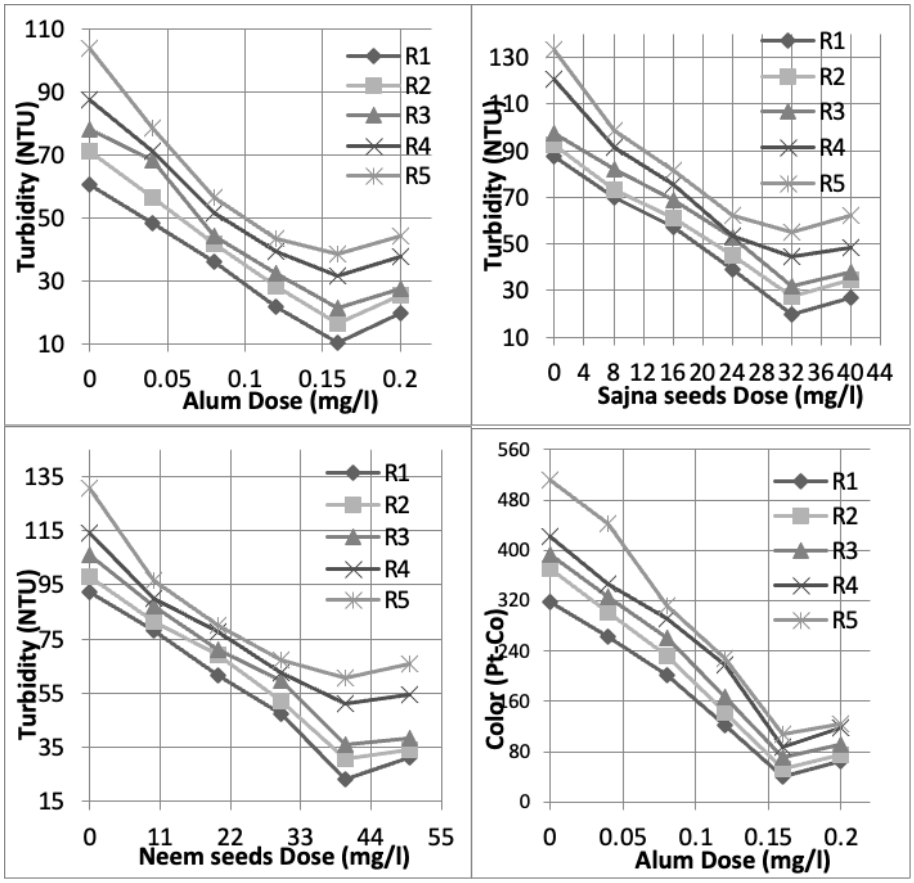
Figure 1: Jar Test set

4 Results and Discussion

In this study, Sajna and Neem seeds were selected as bio coagulants. The optimum dose for the Sajna seeds coagulant was found as 32 mg/l for the river water. The optimum dose for the Neem seeds coagulant was found as 40 mg/l for the river water. It is found that the turbidity removal efficiencies of the coagulants varied from 94.5 to 96.5% compared to alum coagulation for river water. Turbidity removal of Sajna seeds coagulant is found to be approximately 1.7% higher than Neem seeds for river water. The color removal efficiencies of the coagulants varied from 83.6 to 87.1% compared to alum coagulation for river water. Color removal of Neem seeds coagulant is found approximately 3.5% higher than Sajna seeds for river water. It is also observed that the turbidity and color removal efficiency linearly decrease with increasing values initial values of raw water for river water.

4.1 Physical and Chemical Properties of Treated Water

Water samples collected from Bhairab river was treated using both bio-coagulants (Sajna and Neem seeds) and chemical coagulant (Alum). For alum coagulation, doses of alum were varied from 0 to 0.20 with an increment of 04 mg/l. Table 4 and Figure 4 shows the variation of the turbidity of the river water after the alum coagulation. It was seen that the optimum dose was found 0.16 mg/l for the alum coagulation for all samples.



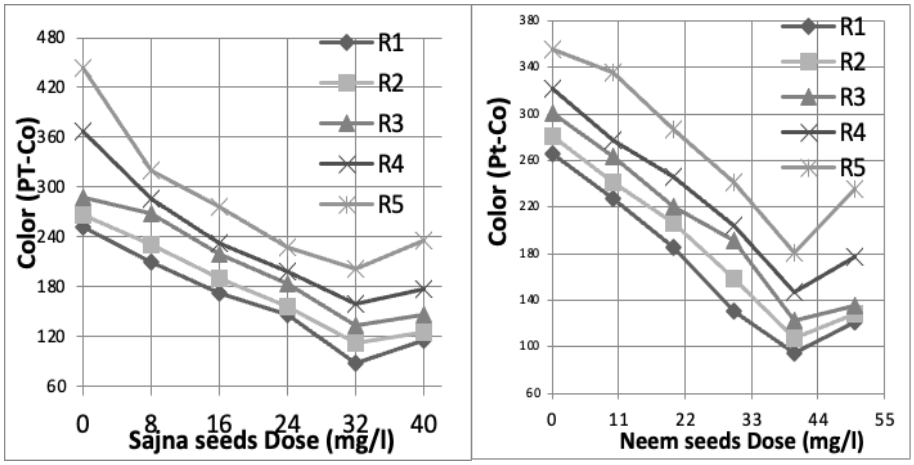


Figure 2. Variation of turbidity and color after using alum & bio coagulants.

Note: R1=River water sample 1, R2=River water sample 2, R3=River water sample 3, R4=River water sample 4, R5=River water sample 5.

For Bio-coagulation, Sajna and Neem seeds were used. The doses were varied from 0 to 40 with an increment of 8 mg/l for the Sajna seeds and 0 to 50 with an increment of 10 mg/l for the Neem seeds. From Figure 1., for turbidity and colour removal, it was seen that the optimum dose of the alum, Sajna and Neem seed coagulants were found as 0.16 mg/l, 32 mg/l and 40 mg/l for the coagulation of all samples respectively. It was seen that the values of pH were almost constant that varies from 7.68 to 7.76 for river water for Sajna seeds and for Neem seeds it varies from 7.66 to 7.76 for alum coagulation. After Alum, Sajna and Neem coagulations the pH and conductivity of river water does not varies too much, it remains more or less same.

The values of turbidity of raw samples were varied from 234 to 533 NTU for river. After coagulation it varied from 10.2 to 38.5, 19.5 to 55.3, 23.2 to 60.4 NTU for river water for alum, Sajna and Neem seeds coagulants, respectively. The values of color of raw samples varied from 407 to 674 Pt-Co for river water. After coagulation it varied from 40 to 107, 88 to 201, 95 to 181 Pt-Co for river water for alum, Sajna and Neem seeds coagulants, respectively.

4.2 Turbidity and Color Removal Efficiency of Coagulants

Turbidity and color removal efficiency of three coagulants alum, Sajna and Neem seeds were calculated. Using Equation (1). Table 2 and 3 shows the turbidity and color removal efficiency for the three coagulants.

$$Removal\ Efficiency\ (\%) = \frac{(A-B)}{A} \times 100 \quad (1)$$

Where, A = Initial value of raw water sample
B = Final value after the coagulation

Table 2. Turbidity Removal Efficiency of each coagulant

Water sample		Initial Turbidity (NTU)	Turbidity Removal Efficiency (%)			Efficiency of bio-coagulants with that of Alum (%)	
			Sajna seeds	Neem seeds	Alum	Sajna seeds	Neem seeds
River water	R1	234	91.5	90.1	95.3	96.0	94.5
	R2	288	90.8	89.3	94.3	96.3	94.7
	R3	327	90.3	89	93.9	96.2	94.8
	R4	447	89.9	88.5	93.2	96.5	94.9
	R5	533	89.4	87.8	92.8	96.3	94.6

Table 3. Color Removal Efficiency of each coagulant

Water sample		Initial Color (Pt-Co)	Color Removal Efficiency (%)			Efficiency of bio-coagulants with that of Alum (%)	
			Sajna seeds	Neem seeds	Alum	Sajna seeds	Neem seeds
River water	R1	407	78.1	76.7	90.2	86.6	85.0
	R2	439	75.2	75.6	88.3	85.2	85.6
	R3	488	73.6	74.8	86.9	84.7	86.1
	R4	556	71.9	73.6	84.8	84.8	87.0
	R5	674	70	72.9	83.7	83.6	87.1

It is found that the turbidity removal efficiencies of the coagulants are varied from 94.5 to 96.5% with compared to alum coagulation. Turbidity removal of Sajna seeds coagulant is found approximately 1.7% higher than Neem seeds for river water. The color removal efficiencies of the coagulants are varied from 83.6 to 87.1% with compared to alum coagulation. Color removal of Neem seeds coagulant is found approximately 3.5% higher than Sajna seeds.

Linear correlations for the turbidity removal efficiency are proposed by Equations (1) to (3) for the all coagulants.

$$Sajna\ (river\ water): \quad y = 92.717 - 0.0064x; \quad R^2 = 0.93 \tag{1}$$
$$Neem\ (river\ water): \quad y = 91.459 - 0.0069x; \quad R^2 = 0.95 \tag{2}$$
$$Alum\ (river\ water): \quad y = 96.707 - 0.0077x; \quad R^2 = 0.92 \tag{3}$$

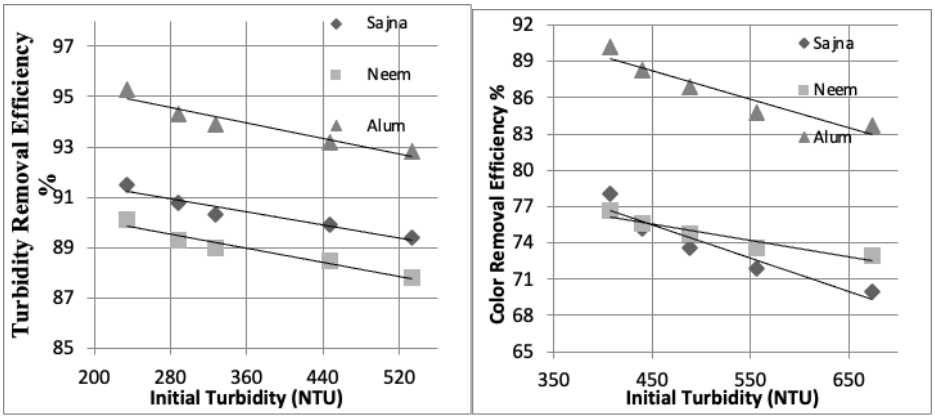


Figure 3. Variation of the turbidity and color removal efficiency for the three coagulants.

Linear correlations for the color removal efficiency are proposed by Equations (4) to (6) for all coagulants.

$$Sajna\ (river\ water): \quad y = 81.748 - 0.0137x; \quad R^2 = 0.92 \tag{4}$$
$$Neem\ (river\ water): \quad y = 87.947 - 0.0277x; \quad R^2 = 0.90 \tag{5}$$
$$Alum\ (river\ water): \quad y = 98.820 - 0.0235x; \quad R^2 = 0.91 \tag{6}$$

It is also observed that the turbidity and color removal efficiency linearly decrease with increasing values initial values of raw water for river.

5 Conclusions

This study showed the performances of two types of bio-coagulant such as Sajna and Neem seeds are used for the treatment of river water. It is found that the turbidity and color removal efficiencies are satisfactory for both the coagulants which are significant for use as a coagulant in water treatment purpose. Linear correlations for the turbidity and color removal efficiencies are also proposed. Such bio-coagulants have found a high degree of significance for use as a coagulant in water treatment purpose. The main advantages of using natural plant-based coagulants as water treatment material are apparent; they are cost-effective, unlikely to produce treated water with extreme pH and highly bio-degradable. The use of bio-coagulant would be a possible alternative to chemical coagulant for the same treatment of drinking water in rural areas and developing country like Bangladesh. Hence, it is concluded that this natural coagulant such as Sajna and Neem seeds could be used as coagulant for surface water treatment purposes. In this study, performance study of two bio-coagulants Sajna and Neem seeds are performed as coagulants. Similar research could be conducted using other easily available natural bio-coagulants. Also, some other important physical and chemical properties such as conductivity, total solid, total dissolved solids, total suspended solids and Total coliform could also be analyzed. In this study, bio-coagulants are used for the treatment of drinking water only, similar research could be conducted for industrial waste water treatment using bio-coagulant.

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